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CONTENTS

The Role of Memory in the Acquisition of Concepts: H. E. CAHILL AND C. I. HOVLAND 137

The Relationship of Induced Muscular Tension, Tension Level, and Manifest Anxiety in Learning: O. I. LOVAAS 145

Studies in Incidental Learning: VIII. The Effects of Contextual Determination: L. POSTMAN AND P. A. ADAMS 153

The Magnitude of the Pulfrich Stereophenomenon as a Function of Target Velocity: A. LIT 165

Evidence for a Selective Process during Perception of Tachistoscopically Presented Stimuli: J. BROWN 176

Effect of Number of Doublets upon Verbal Maze Learning: J. F. VOSS AND J. A. ZIEGLER 182

The Relationship of Test and General Anxiety, Difficulty of Task, and Experimental Instructions to Performance: I. G. SARASON AND E. G. PALOLA 185

Visual Pattern Identification as a Function of Fill and Distortion: W. A. HILLIX 192

Effect of Amount of Preconditioning Training upon the Magnitude of Sensory Preconditioning: D. R. HOFFELD, S. B. KENDALL, R. F. THOMPSON, AND W. J. BROGDEN 198

Supplementary Report: The Relationship of Induced Muscular Tension to Manifest Anxiety in Learning: O. I. LOVAAS 205

Supplementary Report: Retention and Transfer of Responses to Stimulus Classes: K. E. LLOYD 206

Supplementary Report: Two-Choice Behavior of Monkeys: W. A. WILSON, JR. 207

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THE ROLE OF MEMORY IN THE ACQUISITION OF CONCEPTS [1]

HUGH E. CAHILL [2] AND CARL I. HOVLAND

Yale University

In the learning of concepts under naturalistic conditions there is typically a time interval between successive instances and also between the presentation of instances and the testing of concept attainment. An important research problem is thus generated concerning the effect of memory in the acquisition of concepts. This problem also is of significance in the simulation of cognitive behavior by high speed computers (Hovland, 1959). With computer simulation the first approximations often involve conditions of unlimited memory. In human learning, however, forgetting, due to interference and other factors, is typical and must be understood and incorporated into the model if programing of computers is to simulate human performance successfully.

In the present experiment the effect of memory factors is analyzed by comparing performance in acquiring concepts under conditions simulating unlimited memory storage with that under conditions more closely simulating human learning where forgetting of previous exposed instances is compounded with the inference phase of concept acquisition. Instances were successively exposed, the "unlimited memory" condition being simulated by allowing all of the instances to remain in view and the "limited memory" condition by allowing only the last presented instance to remain exposed.

METHOD

The concept model utilized by Hovland (1952) and Hovland and Weiss (1953) was employed. This involves a "closed" system in which the character of the concept to be learned is specified to *S*, i.e., he is told what dimensions are involved, how many are relevant, and the number of values for each dimension. The concept instances were constructed with three values within three stimulus dimensions: form, (triangle, circle, or cross), shading (white, gray, or stripe), and number (one, two, or three). In the present study the concept was transmitted entirely by negative instances.

For the practice series the concept involved only one value of one dimension. An example of such a concept would be *circu-*

[1] Research funds were generously provided by the Behavior Science Division of the Ford Foundation. The study was conducted during 1953–54 and preliminary results were reported at the APA meetings, September 1954. The authors wish to thank Fred Sheffield for careful reading of the manuscript.

[2] Now at Psychological Research Associates, Inc., Encino, California.

larity. Negative instances would be those containing one, two, or three white, gray, or striped crosses or squares. Three negative instances appropriately chosen would suffice to exclude all but the correct concept.

For the experiment itself two more complex conjunctive concepts were used. One, hereafter designated as a Level 1 concept, involved two relevant dimensions (one irrelevant) with one value out of three correct for each dimension (e.g., a white circle). Twenty-seven concepts of this type may be generated. Each negative instance excludes three concepts but due to redundancy 10 negative instances are required to exclude all hypotheses except the correct one.

The other, more complex two-valued concept used in the main experiment involved two relevant dimensions (one irrelevant) with two values out of three correct for each dimension (e.g., white and gray circles and triangles). This problem will be hereafter described as one of Level 2. Again 27 concepts can be generated. Here, however, each negative instance eliminates 12 possible concepts. Four negative instances eliminate all but the correct concept (again there is some redundancy necessary).

A "guess-the-correct-concept" technique was employed. The *S*s wrote down after each instance was presented their best guess as to the concept involved, thus providing a continuous record of the types of hypotheses used by *S*. A practice booklet and test booklet were devised which contained all of the necessary experimental information given to *S*s. The practice booklet contained three pages of general orientation instructions which indicated by verbal definition and pictorial examples the stimulus universe, the nature of negative concept instances and the structure of the concepts to be employed. To permit *S*s to test in practice their assimilation of these materials two concept problems, one of Level 1 and one of Level 2, were also included in each practice booklet.

Simultaneous ("unlimited memory") series. Here new instances were exposed at 30-sec. intervals, with the instance remaining in view once it had been exposed. Each page containing all previous instances plus the new one. Answer sheets, on which *S* was required to record his tentative concept hypotheses, were alternated with each of the pages portraying instances.

Successive ("limited memory") series. This method also involved exposing each instance for 30 sec., but at the end of this period the instance was no longer available. This was effected by exposing only the new instance on successive pages of the booklet. Answer sheets were again interspersed between pages of instances.

During practice a Level 1 problem was presented by the successive method. A Level 2 problem was given by simultaneous presentation and also by the successive method.

During the main experiment two Level 1 problems and two Level 2 problems were presented. One problem at each level was given by the simultaneous presentation ("unlimited memory") and one by the successive presentation ("limited memory") technique.

The concepts in the practice and in the learning series differed in the particular combination of dimensions and values which they contained. In all, three concepts were devised for each level of problem complexity so that each *S* received one problem of each level during practice and the remaining two in the learning-testing phase. The problems employed were so arranged that each third of the total group of *S*s received each type of practice problem.

Twice the minimal required number of instances was given for each problem in an attempt to insure a reasonably high level of performance while at the same time extending the opportunity to obtain a record of *S*'s intervening tentative concept hypotheses. No indication was given to *S*, however, as to when a sufficient amount of information for deducing the correct concept had been presented. Accordingly it was assumed that *S*s looked upon the instances presented as forming one continuous series.

Subjects. Thirty-six Yale undergraduates hired through the university employment bureau served as *S*s in this experiment. The *S*s were tested in groups of two to five depending on their availability. Two *S*s who were unable to learn the Level 1 problem even under simultaneous conditions were replaced, as were seven *S*s who failed to follow instructions, such as those requiring *S*s to give a guess after each instance.

After each *S* was given a practice and experimental booklet *E* read aloud the three pages of orientation material while *S*s read the same material silently. In this material *S* was exposed to the stimulus universe and was shown a number of instances of concepts involving a single value each (practice-level problems) and was introduced to the role of negative instances as they are used in presenting information pertinent to simple concept problems. The *S*s were then asked to solve three practice-level problems. They typically accomplished this in 2 min. or less,

thus indicating their assimilation of the explanatory materials given them to that point. Subsequently *Ss* were practiced on problems of Levels 1 and 2. Since all of the relevant experimental materials were contained in booklets it was possible to have each *S* work on a different problem during the same experimental session.

Following the practice session *E* emphasized the importance of the standardized test conditions which required *Ss* to turn the pages in their test booklets exactly on cue at the end of each 30-sec. period. Specifically 20 sec. were allowed for perusal of the instances and up to 10 sec. for recording of tentative concept hypotheses. No questions were permitted during the learning-testing phase and *Ss* were given their four test problems consecutively with a rest period of about 2 min. intervening between problems.

Results

The extent to which memory plays an important role in concept learning is shown by the comparison of the number of correct statements of the concepts after the presentation of the minimum number of instances (after Trial 10 for Level 1 problems and after Trial 4 for Level 2 problems) under the simultaneous and successive conditions. Eleven test trials were involved in the former series (after Instances 10 through 20) and five in the latter (after Instances 4 through 8). Success scores determined on this basis were not normally distributed and tests of significance of success as a function of type of stimulus presentation and problem complexity level were made by the Wilcoxon (1945) nonparametric test for paired-replicates. The results of these tests, as well as the median number of correct responses, for the different stimulus presentation conditions are summarized in Table 1. Here it may be seen that concept attainment under simultaneous presentation is markedly superior at both levels of problem difficulty ($P < .001$ for Level 1 and $P = .02$ for Level 2). The findings replicate those of Hovland and Weiss (1953) in showing poorer performance when previous instances must be retained in memory rather than being directly available for inspection.

TABLE 1

Number of Correct Statements of Concept as a Function of Type of Stimulus Presentation and Problem

Condition	No. Nonzero Differences	Median	Diff.	One-Tail *P*
Level 1 problem				
Simultaneous	34	10.8	10.4	.001
Successive		0.4		
Level 2 problem				
Simultaneous	28	4.6	4.2	.02
Successive		0.4		

Note.—Level 1 problem involved instances 10 through 20, with maximum score of 11; Level 2 problem involved instances 4 through 8, with maximum score of 5.

Errors were analyzed to determine how many were responses incompatible with the immediately presented instance and how many were incompatible with instances presented somewhere earlier in the series. The former may be described as "perceptual-inference" errors since they are responses to stimuli physically available and constitute failure either to perceive correctly the stimulus presented or to make the appropriate inference as to possible concepts from it.

Perceptual-inference errors were reltively infrequent. With the Level 1 problem 5 *Ss* made a total of 6 errors under simultaneous conditions and 7 *Ss* made a total of 8 errors under successive conditions. With the Level 2 problem 12 *Ss* made a total of 24 errors under simultaneous conditions and 15 *Ss* made a total of 21 under successive. As would be expected, no reliable difference between simul-

taneous and successive conditions was obtained for the just-presented instance. The difference in number of errors at the two levels of difficulty is, however, significant ($P < .01$).

The *Ss* who made these perceptual-inference errors not unexpectedly had greater difficulty in learning the concepts. These results are reported in Table 2. The *Ss* were divided into "high" and "low" groups in terms of the number of "perceptual-inference" errors made. The significance test is based on the Mann-Whitney *U* technique (1947). The number of *Ss* in the high and low groups differ among the various conditions since *Ss* could not sensibly be divided at the median number of errors. It can be seen that the differences were greater at the greater complexity level and in the simultaneous as opposed to the successive presentation conditions. Only in the sucessive conditions at Level 1 did the difference fail to approach at least marginal significance. Particularly interesting also is the fact that a difference approaching significance was obtained in the simultaneous condition at Level 1 where only five *Ss* committed perceptual-inference errors. Thus it appears that at even the simplest level the task of formulating a concept compatible with the immediately presented instance exhibits the operation of wide individual differences which significantly affect over-all performance.

The other type of error mentioned above involves the stating of a concept hypothesis which is compatible with the just-presented instance but fails to take into account information received on an earlier trial. These "memory" errors are quite numerous and were analyzed in detail. They likewise are highly correlated with success in attaining the correct concept. The *Ss* are divided into "high" and "low" groups in terms of the number of memory errors made. Significance tests are again based on the Mann-Whitney *U* technique.

An analysis was made of the number of concept hypotheses which were incompatible with information on instances varying numbers of trials earlier. For example, on Trial 7 an *S* gives an hypothesis as to the correct concept. This may or may not be consonant with the instance just presented. One can also check to see whether it is or is not consonant

TABLE 2

SUCCESS IN CONCEPT ATTAINMENT AS RELATED TO NUMBER OF PERCEPTUAL-INFERENCE ERRORS

Condition	Level	Perceptual-Inference Performance						P*
		High			Low			
		N	Median Perceptual-Inference Errors	Median Correct Answers	*N*	Median Perceptual-Inference Errors	Median Correct Answers	
Simultaneous	1	31	0	10.8	5	1.1	8.0	.06
Successive	1	29	0	3.8	7	1.1	0.4	.12
Simultaneous	2	24	0	10.9	12	2.0	0.4	<.001
Successive	2	21	0	7.0	15	1.1	0.1	.02

* One-tail difference in number of correct answers.

TABLE 3

SUCCESS IN CONCEPT ATTAINMENT AS RELATED TO MEMORY CAPACITY

Condition	Level	Memory Capacity						P*
		High			Low			
		N	Median Memory Errors	Median Correct Answers	N	Median Memory Errors	Median Correct Answers	
Simultaneous	1	24	0.0	11.0	12	2.2	8.0	<.001
Successive	1	17	5.7	7.0	19	11.5	0.0	<.001
Simultaneous	2	19	0.0	11.0	17	2.4	0.4	<.001
Successive	2	17	0.3	10.8	19	5.4	0.0	<.001

* One-tail difference in number of correct answers.

with the instance presented one trial earlier, two trials earlier, etc. In the case of the simultaneous series one has physically available the earlier instances and differential failure to utilize earlier instances is primarily attributable to failure to consider the instances presented earlier. But in the case of the successive presentation incompatibility is also attributable to failure to remember the earlier instances and/or to remember their implication. It is thus a sensitive measure of memory. The conditions for the two series are otherwise identical so that the simultaneous series constitutes a "control" condition for the successive. The Level 1 problem provides the most extensive data since a longer series of instances is involved than is the case with the Level 2 problem. The number of errors was calculated by determining the number of occasions in which a response was given which was incompatible with the implications of instances varying numbers of trials earlier. Since the distribution of *Ss'* errors was J-shaped, medians are employed. The number of errors for each degree of remoteness from the immediately presented instance are given in Table 4. Also presented are the number of opportunities for making an error. The variation in number of opportunities is attributable to the fact that there is some redundancy inevitable in the series so that sometimes a concept hypothesis is excluded more than once. Such cases are excluded from the analysis with the result that there are fewer opportunities to make errors as the degree of remoteness increases. While it would have been possible to compute errors up to 19 degrees of remoteness, the analysis was restricted to the range in which at least 50% of the initial number of opportunities was permitted. This gave a range from

TABLE 4

MEDIAN NUMBER OF ERRORS: RESPONSES INCOMPATIBLE WITH INSTANCES PRESENTED VARYING NUMBERS OF TRIALS EARLIER

Condition	Degree of Remoteness							
	0	1	2	3	4	5	6	7
Successive	.03	.14	.25	.40	.36	.66	.67	.74
Simultaneous	.06	.12	.03	.05	.03	.00	.03	.02
Concepts excluded*	78	78	68	65	57	55	50	45

* Number of concepts excluded for the first time by the instance being considered.

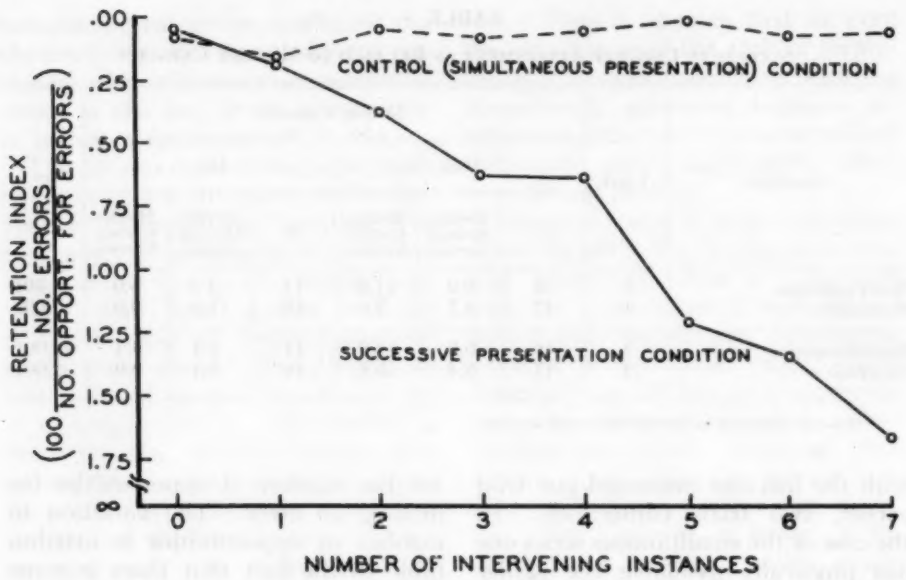

FIG. 1. Retention index for information after varying numbers of intervening instances.

zero to seven degrees of remoteness. For presentation of the decrease in utilization of the information contained in the instances more remote in the series it seemed appropriate to use a ratio of errors to number of opportunities. Accordingly, in the graph presented in Fig. 1 the median number of errors is divided by the number of opportunities for making such an error. This fraction is then multiplied by 100. The higher the value of this index, the greater the extent of "forgetting." The solid line indicates the changes in ratio with degree of remoteness between the concept given and the instance relating to that hypothesis for the successive conditions, in which memory for past instances was required. Results for the simultaneous presentation condition provide a good control for any possible contamination or selection; they are given by the broken line. Clear evidence of increased "forgetting" with increased remoteness is obtained. The divergence in slope between the two conditions is highly significant ($P < .001$). Comparable results are found for the Level 2 problem, but only three points can be utilized.

Analysis was also made of the extent to which information presented early in the series is correctly utilized as compared with that presented late, for instances of the same degree of remoteness. Figure 2, in which the abscissa and ordinate are in the same units used in Fig. 1, shows the memory effects for instances presented early and late in the series. The broken line represents the error ratio for concepts excluded early (Trials 1–3) and the solid line portrays the ratio for concepts excluded late (Trials 7–10). (To make the number of opportunities for error similar, four instances were used for the later series and three for the earlier series.) The results indicate the operation of a moderately strong

"primacy effect," i.e., the information presented early in the series is utilized more effectively than the information presented later on. The difference in slope is significant ($P < .01$). Both primacy and recency effects can be said to be operative—primacy as shown by the higher level of retention of the early series of instances, and recency as shown by the fact that the curves decline with increased degree of remoteness for both the early and late series.

Discussion

The present study indicates that a very low proportion of errors in concept formation of the type studied here is attributable to failure to assimilate the information perceptually available and to draw the appropriate inferences concerning the concept being sought. More of the errors are attributable to failure to remember earlier instances in such a way as to see their implications. These errors increase progressively with increasing numbers of intervening instances. The decline in retention, the "forgetting curve," is approximately linear over the range examined.

These data indicate a close tie between phenomena of concept acquisition and those of memory (cf. also Underwood, 1952). Further studies may profitably be devoted to exploring the overlap between these areas, by varying the similarity of materials and extending the range of time intervals.

For machine simulation of concept learning some explicit treatment of memory effects is necessary. Up to the present it has been simpler to assume unlimited memory, as in the model developed by Hovland (1952) where the implications of different types of instances is explored when *S* knows the nature of the concept task and is able to retain all of the information presented. For realistic simulation of more typical concept learning, however, we must cover also situations where the knowledge of the type of concept is quite incomplete ("open") and also where there is typical human fallibility of memory.

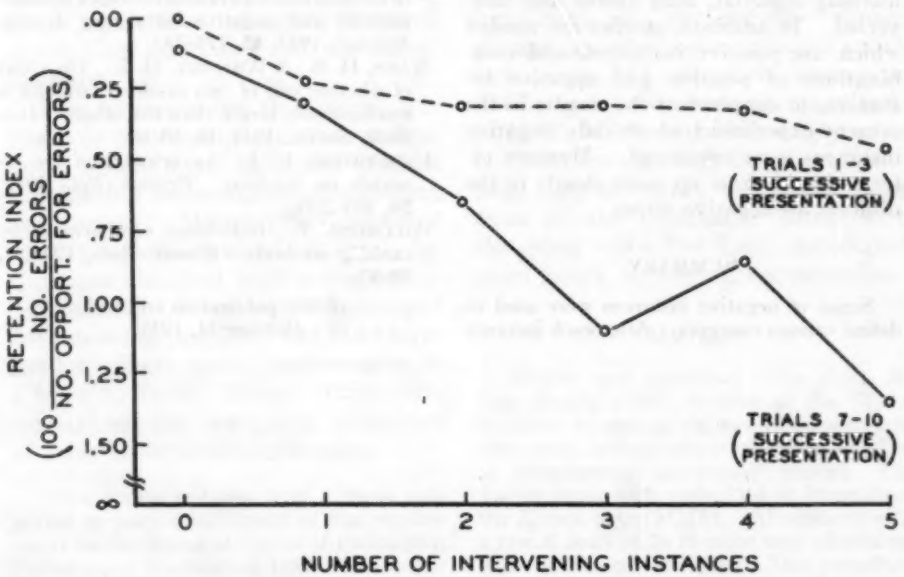

Fig. 2. Retention indices for information presented early in series (Trials 1–3) and late in series (Trials 7–10) after varying numbers of intervening instances.

The intriguing task is to build this forgetting into the machine in the most effective manner. It would be relatively simple to do this on an empirical basis, following known results for the function. What is more challenging is to build the memory function into the computer in ways which best meet theoretical requirements concerning interference effects as a basis for the loss. Work on this formulation for simulation is currently underway in our laboratory.

The type of "primacy effect" obtained in this experiment deserves further investigation. Two types of explanations suggest themselves for further exploration. It may be that material presented early is attended to more closely and is in some way more prominent and impressive. Or it may be that at the outset there are fewer instances which must be considered in drawing inferences as to the appropriate concept while later more instances have to be considered and remembered, and this leads to greater difficulty.

The generality of the present findings on memory is not known. Replication is needed with different types of concept learning material, both verbal and nonverbal. In addition, studies are needed which use positive instances, and combinations of positive and negative instances, to supplement the results in the present experiment where only negative instances were employed. Memory effects should show up most clearly in the difficult all-negative series.

Summary

Series of negative instances were used to define various concepts. After each instance *S* was instructed to guess the characteristics of the concept. Under experimental conditions each instance was removed from view when the next instance was presented. Under control conditions all prior instances remained in view.

Memory effects were studied by comparing the number of cases where the guess was incompatible with information presented in prior instances under these two conditions. Guesses were seldom incompatible with the instance just presented but under the experimental conditions were increasingly discrepant from instances further removed, giving rise to a characteristic "forgetting curve." The rate of forgetting was less rapid for the instances presented early in the total series than for those presented late. Significant individual differences were obtained, indicating that *S*s who made more "perceptual-inference" and "memory" errors had greater difficulty in acquiring the concepts.

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THE RELATIONSHIP OF INDUCED MUSCULAR TENSION, TENSION LEVEL, AND MANIFEST ANXIETY IN LEARNING [1]

O. IVAR LOVAAS

University of Washington

This study investigated the relationship between manifest anxiety (MAS), individual differences in muscular tension (MT), and induced muscular tension (IMT) in a learning task. The *S*s were split into a high- and low-scoring group on MAS, and a high- and low-scoring group in terms of spontaneous eyeblink rate (MT). Meyer (1953) has argued for the efficacy of the eyeblink rate as a measure of muscular tension. The performance of these groups could be observed under various IMT conditions. Paired-associate learning was employed. Adjectives were paired in such a manner as to produce pairs of high and low degrees of association and competing pairs, the latter being pairs where two or more response words were associated with the stimulus word.

The rationale for this study was based on previous empirical investigations which have indicated a close relationship between muscular tension and anxiety. Malmo (1957) reported that people adjudged anxious by clinicians obtained high scores on indices of MT. Lovaas (1960) obtained data showing that IMT and MAS have similar effects upon performance in a learning task. Meyer (1953) conceptualized the energizing properties of drive to be muscular tension.

Spence (1956) has presented a theoretical framework and empirical observations which imply that *S*s who are differentiated on MAS also are differentiated on D; he also related D to performance in paired-associate learning. In view of the close relationship of IMT and MT to MAS, this study sought to investigate the possibility whether all three variables could be related to each other by Hull's generalized drive and whether they would be supported as D variables in paired-associate learning. If MAS, MT, and IMT were to be supported as D variables, then (*a*) the joint occurrence of MAS and IMT and of MT and IMT would summate in their effect upon performance; (*b*) performance should change in the same manner with increasing MT as with increasing IMT; and (*c*) increasing magnitude of IMT, MAS, and MT, singly or in combination, should be more beneficial to the highly associated pairs than to the competing pairs, with the effect upon the lowly associated pairs falling between these extremes.

METHOD

Subjects and apparatus. The short 20-item Bendig (1956) revision of the Taylor Manifest Anxiety Scale was administered to 110 male, undergraduate students enrolled in introductory psychology courses. The Taylor items were embedded in items from the K scale of the MMPI. All students with a raw K score of 24 or more were eliminated from further consideration. This procedure eliminated 12 students from the extreme low end of the distribution. Of the remaining

[1] This article is taken from a thesis submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, University of Washington, 1958. The author is indebted to Moncrieff H. Smith, Jr., under whose direction the thesis was prepared.

TABLE 1

SETS OF PAIRED ASSOCIATES

Set 1:		Set 2:	
Stimulus	Response	Stimulus	Response
Adept	Gallant	Adept	Gallant
Complete	Thorough	Empty	Vacant
Distant	Bashful	Mammoth	Wanting
Empty	Vacant	Wicked	Evil
Frigid	Balmy	Complete	Gentle
Insane	Crazy	Frigid	Heavy
Mammoth	Wanting	Pious	Tired
Pious	Devout	Urgent	Wholesome
Urgent	Extinct	Barren	Grouchy
Wicked	Evil	Little	Headstrong
		Roving	Double
		Tranquil	Leading

98 students the 32 lowest scoring students were selected for the low-MAS *Ss* (M = 1.9, range = 0–4), the 32 students who scored highest on the scale were selected for the high-MAS *Ss* (M = 8.2, range = 5–17). None of the *Ss* had experience with the kind of learning task presented. They were unaware of the basis for selection and of the purpose of the experiment.

Each pair of words was typed on a card and the cards were mounted on two screws. As the screws rotated they brought the cards forward to an exposure window and dropped one card every 4 sec. A shutter mechanism allowed the stimulus word to be shown for 1.7 sec. of the 4-sec. interval, then exposed the response word for 2.3 sec. Inadequacies in the apparatus allowed an SD of about .1 sec. in the various exposure times.

A Smedley dynamometer was located on each side of the exposure window, about 25 in. apart and about 20 in. from *S*. The handles were padded. The *Ss* alternated hands from one trial to another. The pointer on the dynamometer closed a circuit which lighted a bulb, located 2 in. above one corner of the exposure window, whenever the pressure exerted by *S* was ±3 lb. of the pressure required of him.

Material and procedure. On arriving for the experiment each *S* squeezed the dynamometers, one at a time, as hard as he could for 30 sec. each. Except in the zero IMT condition, *S* would squeeze at a designated fraction ($\frac{1}{8}$, $\frac{1}{4}$ or $\frac{1}{2}$) of the maximal pressure exerted during the 30th sec. on the respective handle. The tension signal light was kept on by *S* during each trial. The *Ss* in the zero IMT condition merely gripped the handles. The contact on the dynamometer allowed a pressure of only 3 lb. to turn the light off. This condition was introduced to equalize distracting effects from the light on the groups.

The *S* was told that he would work for a predetermined number of trials, that if he got all correct at one time he should attempt to get all correct again, and that he should do his best on each trial. The instructions were designed to avoid the incentive motivation effects of the tension conditions which might have operated if *Ss* knew that faster work would accomplish earlier release.

The *S* was given a practice session of six trials on 10 paired nouns, with the use of the dynamometers begun on Practice Trial 3. A 1-min. rest period followed the practice trials after which two sets of paired adjectives were learned (see Table 1). All *Ss* learned Set 1 first, then Set 2.

Using Haagen's (1949) word list, five "H pairs" were selected for Set 1 in such a manner as to maximize strength of association between the paired stimulus and response words. The remaining five pairs "L pairs" were selected in such a manner that the stimulus word was paired with a response word with which it had little associative connection. In addition, the pairs were selected to minimize association value between one pair and another. No beginning letter or suffix was repeated either in the stimulus words or in the response words. Set 2 was composed in the following manner. For the "H pairs" four pairs were the same as those used in Set 1. These had high ${}_{s}H_{R}$ since *Ss* had had a number of trials on these pairs immediately prior to being presented with Set 2. For the four "C pairs," the stimulus words were the same as in Set 1 but the response words were changed, thus creating many competing responses. The "L pairs" were four altogether new pairs selected to have low associative value between the stimulus and response words, in relationship to the "H pairs." As with Set 1, the pairs on Set 2 were selected to minimize association between one pair and another.

The two MAS groups were split into four subgroups having different levels of induced muscular tension: control group, which merely gripped the handles; and groups with $\frac{1}{8}$, $\frac{1}{4}$, and $\frac{1}{2}$ pressure on the hand dynamometer. For each condition on Set 2 there were two *Ss* from each of the conditions on Set 1, a total of eight *Ss* for each of the conditions. This assignment of *Ss* provided for the testing of possible interaction of pressure on Set 1 with performance on Set 2.

Set 1 was presented for a minimum of two consecutive errorless trials or for a maximum of 21 trials. There was a 4-min. interval

between presentation of Sets 1 and 2 during which *S* rested and *E* changed the contacts on the dynamometer if *S* had been assigned to a different pressure condition on Set 2. Instructions for Set 2 included a statement to the effect that some of the pairs were the same as in Set 1 and some were different. Set 2 was presented for a maximum number of 14 trials. The pairs were shuffled after each presentation to avoid serial effects. Intervals between the trials were held constant at 10 sec. The *S*s' performance on the learning task was recorded in terms of number of correct anticipations for each pair. All correct anticipations were pronounced during the 1.7-sec. anticipation interval.

Number of eyeblinks was counted on sight by *E* on Trial 2 of the practice set, and on Trials 1, 11, and 21 (or on the trial following two consecutive errorless trials) on Set 1. Only complete closures of the eyelid were counted. The *E* was aware of *S*'s classification with respect to both MAS and IMT at the time the eyeblinks were counted.

Results

The relationship of MAS and IMT. Means and *SD*s for correct anticipations on pairs in Sets 1 and 2 for the high- and low-MAS groups under the IMT conditions are presented in Table 2. The analysis of variances on these data shows that only the effects of variation in kinds of pairs were significant ($F = 247.1$ on Set 1; $F = 21.1$ on Set 2; both have $P < .01$). There was no support for a summative effect of MAS and IMT upon performance, or for a differential effect of the magnitude of these variables, singly or in combination, upon kind of pair. There was no effect of pressure on Set 1 on the performance on Set 2.

TABLE 2

Means and *SD*s of Correct Anticipations for High- and Low-MAS *S*s under IMT on Different Pairs in Set 1 and 2

Set 1

MAS		High Association				Low Association			
		IMT				IMT			
		0	¼	½	¾	0	¼	½	¾
High	*M*	75.4	77.5	79.6	80.5	45.8	46.8	54.0	43.5
	SD	15.3	15.2	10.6	7.5	13.6	24.1	23.5	19.2
Low	*M*	83.0	82.9	80.6	72.8	57.5	58.8	44.0	40.9
	SD	7.5	6.7	10.4	13.0	24.4	18.3	23.3	22.2

Set 2

MAS		High Association				Low Association				Competing Association			
		IMT				IMT				IMT			
		0	¼	½	¾	0	¼	½	¾	0	¼	½	¾
High	*M*	44.2	42.0	41.9	38.0	36.4	30.9	28.2	28.9	26.1	17.9	18.0	12.1
	SD	5.6	8.8	8.8	4.8	9.6	9.7	14.0	13.4	11.5	14.1	9.6	9.5
Low	*M*	41.9	45.9	45.1	36.1	32.2	32.4	34.8	23.2	22.8	19.4	23.8	14.9
	SD	11.0	8.1	4.8	12.8	9.3	12.8	4.9	11.7	18.2	16.7	9.7	11.9

TABLE 3

ANALYSIS OF VARIANCE FOR GROUPS HIGH AND LOW ON EYEBLINK RATE AND INDUCED MUSCULAR TENSION ON SET 2

Source of Variation	*df*	*MS*	*F*
High Associated Pairs			
Eyeblink × Pressure	3	162.53	2.528*
Within	36	64.29	
Total	43		
Low Associated Pairs			
Eyeblink × Pressure	3	280.73	2.766*
Within	36	101.50	
Total	43		
Competing Pairs			
Eyeblink × Pressure	3	489.28	3.515**
Within	36	139.19	
Total	43		

Note.—This analysis follows the outline that Snedecor (1946) has given for analysis of variance in the case of disproportionate subclass numbers.
* $P < .06$.
** $P < .05$.

The relationship of MT and IMT. To test the hypothesis of a summative effect of MT and IMT upon performance, *Ss* from the high- and low-MAS groups were matched on basis of their eyeblink rate during Trial 2 of practice. Twenty-two pairs were matched, seven of which were one blink apart, two were two blinks apart, one was five blinks apart, and the remaining pairs had equal blink rates. These 44 *Ss* were split into a low-MT group, those having 12 or fewer blinks; and a high-MT group, those having 13 or more blinks. The mean blink rate of the low-MT group was 7.3 (7.5 for low-MAS *Ss* and 7.2 for high-MAS *Ss*) with an *N* of 24. The mean blink rate of the high-MT group was 21.1 (21.6 for the low-MAS *Ss* and 20.8 for the high-MAS *Ss*) with an *N* of 20. The *Ss* were selected to assure no fewer than four *Ss* for each IMT condition on Set 2.

Table 3 gives the results of the analysis of variance for performance on Set 2 of the high- and low-MT groups under the IMT conditions. The interaction between low- and high-MT groups under various degrees of IMT was significant on the competing pairs ($P < .05$). The *F* associated with the same interactions on the two other kinds of pairs had approximately a $P < .06$. Although this did not meet the statistical criteria for significance, these results might be considered to have reflected a reliable difference because the small number of *Ss* would leave a relatively large error variance and because the means were arranged in the predicted direction. The results of this analysis are presented graphically in Fig. 1.

As can be observed the results were consistent with the summative effect of MT and IMT upon performance. High-MT *Ss* tended to perform better than low-MT *Ss* under 0 and ⅛ IMT conditions, with reversal of this differ-

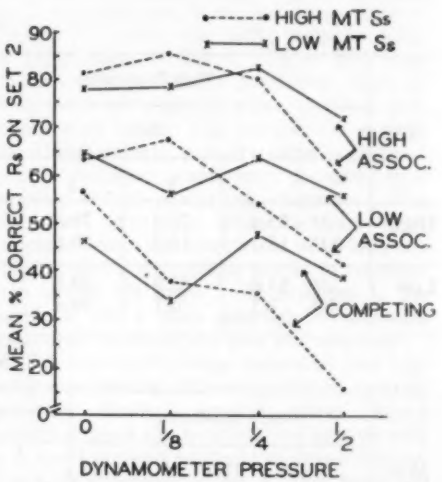

FIG. 1. Paired-associates learning of high- and low-MT (eyeblink rate) *Ss*, matched on MAS (Manifest Anxiety), under various conditions of induced muscular pressure on Set 2. Word pairs of high and low association value and competing pairs were interspersed within the same set, but were analyzed separately.

ence under ¼ and ½ IMT conditions. Under maximal IMT the performance of high-MT *Ss* was consistently inferior to the performance of low-MT *Ss*. The statistical design (Table 3), provided no test for the differential effect of increase in MT or IMT upon kind of pair. However, inspection of Fig. 1 shows the data do not support this hypothesis. Although the curve forms for the high-MT *Ss* were consistent with this hypothesis (the level of IMT associated with optimal performance was higher for the "L and H pairs" than for the "C pairs"), the curve forms for low-MT *Ss* did not reflect this interaction of kinds of pairs and IMT in that the optimal level of IMT was independent of kinds of pairs.

The relationship of MT to performance. It was hypothesized that if MT and IMT were separate *D* variables performance should change in the same manner with increasing MT as with increasing IMT. To test this hypothesis *Ss* were split into four groups on the basis of their eyeblink rates on Trial 2 of practice. Each group had no fewer than 14 and no more than 18 *Ss*. This grouping tended to maximize the *N* of each group and give the same number of points (four) on which to observe the curve relating MT to performance as was the case with the curve relating IMT to performance. Figure 2 presents a graphic description of the relationship of eyeblink rate (MT) to performance on the various pairs of Set 2. This relationship is similar to that based on the performance of *Ss* working under increasing IMT on lists of nonsense syllables (Courts, 1942). Discrepancies between the curves in Fig. 1 and 2 might be due in part to error variation based on small number of *Ss* ($N = 8$) for each group in Fig. 1. This opinion

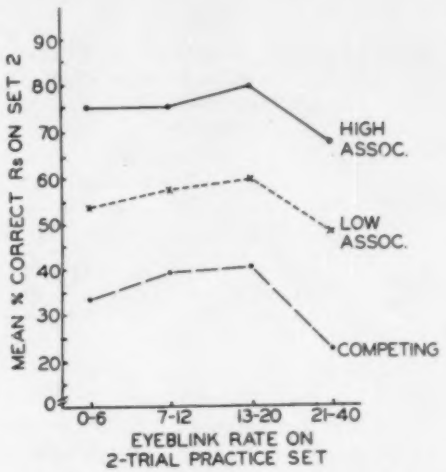

FIG. 2. Paired-associate learning of various MT (eyeblink rate) groups. Word pairs of high and low association value and competing pairs were interspersed within the same set, but were analyzed separately.

is based on the fact that in most research where statistically significant effects have been obtained on the relationship of IMT to performance, the curve forms are either continually increasing or decreasing in relationship to some level of IMT associated with optimal performance.

Additional findings on the eyeblink rate. The reliability of the eyeblink rate could be approximated only because it was not observed twice under strictly comparable conditions. By correlating the counts on Trial 2 of practice, where there was no IMT for any *S*, with the counts on Trial 1 on Set 1, which included all IMT conditions, a product-moment coefficient of .76 was obtained ($df = 62$; $P < .01$).

The relationship of eyeblink rate (from Trial 2 on practice) to MAS scores was curvilinear, with extremely low and high scores on the MAS related to high blink rate. MAS scores around the mean were associated with the lowest mean blink rate

TABLE 4

EYEBLINK RATES ASSOCIATED WITH VARIATIONS IN MANIFEST ANXIETY SCALE SCORES DATA FROM TRIAL 2, PRACTICE SET

Eyeblink Rate	Manifest Anxiety Scale Intervals					
	0–1	2	3–4	5–6	7–10	11–17
N	14	14	13	16	12	7
Mean	14.5	11.1	9.9	14.5	14.5	19.7
SD	10.4	8.7	7.9	6.3	9.6	9.5

and also with the lowest variability in blink rate (Table 4). Eta between MAS scores and blink rate yielded a coefficient of .37, this relationship being based upon an *N* of 76. There was a significant difference in blink rate between the high-MAS and low-MAS groups ($F = 7.06$; $P < .01$).

There was a tendency for the eyeblink rate to increase after Trial 1 (Set 1), then decrease somewhat after mastery was reached.

In the discussion so far, eyeblink rate has been considered as a response which reflected underlying generalized muscular tension. Considering the eyeblink as a response per se, response related to variation in IMT could be observed. Fig. 3 graphically pictures the eyeblink rates from Trial 1 on Set 1 and shows the effect of various degrees of IMT on this response rate.

The MAS × IMT interaction on these data does not quite reach significance ($F = 2.44$; $df = 3$ and 56; $P <$ approximately .06) but the interaction is in the predicted direction. These data are consistent with the summative effect of MAS and IMT in that the level of IMT associated with the highest response rate is lower for high-MAS than for low-MAS *Ss*. It is to be noted that this was the only instance in this study where high-MAS *Ss* had a higher response rate than low-MAS *Ss* under the zero IMT condition, thereby reflecting their hypothesized higher level of *D*.

DISCUSSION

Relationship of MAS, MT, and IMT to each other. It was hypothesized that the joint occurrence of IMT and MAS would summate in their effect upon performance. Data from this study did not confirm this hypothesis. After the data had been collected and analyzed, a study by Meyer and Noble (1958) was published. Their hypothesis concerning the relationship of IMT and MAS, similar to the one for this study, was supported by significant interaction between MAS and IMT. Low-MAS *Ss* tended to improve while high-MAS *Ss* tended to deteriorate with IMT. Their procedure was slightly different from the one in this study in that they used only one IMT condition, employed 20 *Ss* in each of their groups, and had a verbal maze for their learning task. On the basis of the larger *N* in their study it seems preferable to accept their results rather than those from this study.

The hypothesis was confirmed that IMT and MT would summate in their effect upon performance. Thus the level of IMT associated with optimal performance was smaller for high-MT

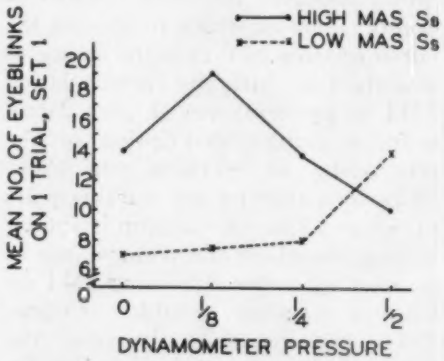

FIG. 3. Relationship of eyeblink rate to induced muscular pressure. High- and low-MAS (manifest anxiety) *Ss* considered separately.

Ss than for low-MT *Ss*. This formulation is similar to Stauffacher's (1937). In brief, his hypothesis stated that poor performers function on a lower level of "normal" tension than good performers and they therefore benefit more than the good ones from IMT. However, Courts (1939) did not find that the optimal dynamometer tension occurred earlier for the good performers than for the poor ones and concluded that the differential effect is slight, if it exists. In a second part of the study, Courts recorded the amplitude of the knee-jerk during the memorization trials for his *Ss*, employing this measure in the same way eyeblink rate was used in this study. Subsequently he separated out the *Ss* who showed the greatest versus the lowest gain from IMT and compared the amplitude of their knee-jerks. He found that *Ss* who failed to benefit from IMT tended to show the greater increase in knee-jerk amplitude during memorization. The latter findings are consistent with the data of the present study.

The data on the relationship of MT and IMT also show that MT and IMT are "interchangeable" variables with respect to the performance observed in this study. Previous research (Lovaas, 1960) has indicated that IMT and MAS may also be "interchangeable." Performance in a learning situation of high-MAS *Ss* was closely approximated by *Ss* assumed to score on a lower level of MAS working under IMT.

In view of the fact that the high-MAS *Ss* emitted a higher eyeblink rate than low-MAS *Ss*, it is suggested caution be used in accepting conclusions based on eyelid conditioning about the more rapid conditioning of high-MAS versus low-MAS *Ss* (Spence, 1956). It is questionable whether this problem could be circumvented by employing high- and low-MAS *Ss* matched on initial eyeblink rate since differentiations on *D* may carry differentiations on eyeblink rate with them.

Relationship of MAS, MT, and IMT to performance. The fact that the differentially associated pairs employed in this study did not discriminate between different magnitudes of MAS, MT, and IMT is inconsistent with Spence's (1956) data on MAS and Lovaas' (1960) data on IMT. The learning task employed perhaps was not sufficiently sensitive. The *E* observed a tendency in some *Ss* to "withhold" the response word for the "H pairs" in Set 2 until they knew which pairs had been changed and which remained unchanged. Any differential effect of tension on the various pairs might then be considered to be more significant than the effect allowed by the statistical design.

Previous research has been concerned with possible changes in the nature of the learning task as learning progresses and the concomitant change in amount of IMT associated with optimal performance. It has been found that the level of IMT associated with optimal performance decreases as learning progresses (Courts, 1942). The smaller magnitude of IMT as learning progresses might reflect merely the increasing magnitude of MT and not bear any relationship to change in the nature of the learning task. This seems possible in view of the findings from this study on the summative effect of MT and IMT and in view of the fact that MT increases after the beginning of acquisition. Data in this study showed that the eyeblink rate increased after the first trial, a finding similar to that of Bartoshuk's (1955) on the EMG. Changes in tension may occur as a function of requirements put upon *S* by both task and *E*. For example, Stennet (1957) found that motivational instructions increased the muscle tension of his *Ss*. If IMT does not facilitate or even impairs performance on "difficult" or "complex" tasks, it might well be that these tasks induce muscle tension in *S*. Adding hand dynamometer tension would bring the level of tension beyond the level associated with optimal performance. In investigations concerned with the effect of IMT on performance, caution should be exercised not to contaminate the effect of this variable with uncontrolled variation in MT.

Summary

Subjects scoring high and low on the Taylor Manifest Anxiety Scale (MAS) worked under various degrees of induced muscular tension (IMT) in paired-associate learning. The *Ss* also were split into a high and low group on the basis of their eyeblink rates, assumed to be an index of individual differences in muscular tension (MT). The learning task, paired adjectives, was constructed with the intent of producing highly associated pairs, lowly associated pairs, and pairs with many competing responses.

It was hypothesized that MAS and IMT, as well as MT and IMT, were related to each other by Hull's generalized drive. Thus MAS and IMT, and MT and IMT, should summate and be interchangeable in their effect on performance. The three variables were related, as Spence has related *D*, to performance in a paired-associate learning task. Hence, increasing magnitude of IMT, MAS, and MT, singly or in combination, should be more beneficial to the highly associated pairs than to the competing pairs, with the effect upon the lowly associated pairs falling between these extremes. While there is support for a summative and interchangeable relationship between MT and IMT, there is no support for a summative relationship between MAS and IMT, or for a differential effect of the magnitude of any of these variables upon the various pairs.

Other findings included a curvilinear relationship between eyeblink rate (MT) and MAS, but high scores on MAS were associated with the highest blink rate.

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STUDIES IN INCIDENTAL LEARNING: VIII. THE EFFECTS OF CONTEXTUAL DETERMINATION [1]

LEO POSTMAN AND PAULINE AUSTIN ADAMS

University of California, Berkeley

Earlier studies in this series have supported the conclusion that intent to learn significantly influences *Ss*' behavior during exposure to the learning materials. What features of the materials *Ss* discriminate and how they respond to individual items and sequences of items depends on whether or not they anticipate a test of retention. Specifically, incidental *Ss* are more selective than intentional *Ss*, i.e., they make fewer differential responses to the learning items. Such responses, we assume, are essential for the differentiation of the materials and also serve to mediate the reproduction of the items at the time of the retention test. There appear to be two major ways in which instructions to learn influence *Ss*' differential responses to the learning materials. First, incidental learners respond selectively to individual items which are relatively familiar or meaningful. Intent to learn serves to extend the range of items which elicit differential responses. Thus, the higher the association value of the items the smaller is the difference between the amounts recalled by intentional and incidental learners (Postman, Adams, & Phillips, 1955). Second, intentional learners are more likely than incidental learners to respond to features of the materials which facilitate linkages among the members of a series. Intentional learners surpass incidental learners in the recall for serial order even when the instructions make no reference to the order of the items (Postman, Adams, & Bohm, 1956).

These findings lead to certain expectations concerning the effects on intentional and incidental learning of varying degrees of contextual determination of the materials. Degree of contextual determination refers to the extent to which the choice of each successive item in a series depends on the items preceding it (Miller & Selfridge, 1950). Two effects of verbal context on retention may be distinguished. First, the presence of sequential dependencies favors intraserial associations, and hence the orderly reproduction of the members of the series. Since instructions to learn increase sensitivity to serial order, sequential dependencies among the items in a list should be more beneficial to serial learning under intentional than under incidental conditions. Second, within a given series, the degree of dependent probability between successive items will usually not be uniform throughout but will vary around some mean value. The more strongly an individual item in such a series is determined by the verbal context the more likely it is to be recalled when that context is reinstated at the time of the retention test. The results of the experiments on association value suggest that the effects of verbal context on the differential recall of individual items should be at least as great under incidental as under intentional conditions. Thus, when the test of retention calls for the reproduction of a series of items,

[1] This research was facilitated by a grant from the Behavioral Sciences Division of the Ford Foundation.

reductions in the uncertainty of the serial order should produce greater increases in recall for intentional than for incidental learners. Selective recall of specific items strongly determined by the verbal context will, however, occur under both conditions.

The present study reports two experiments in which the effects of verbal context on intentional and incidental learning were evaluated. Two methods of varying degree of contextual determination were used. In Exp. I intentional and incidental *Ss* were exposed to lists representing different degrees of approximation to the statistical structure of English. If intentional *Ss* respond to sequential dependencies more consistently than incidental *Ss*, the difference between the two kinds of learners should increase with the order of approximation. In Exp. II recall was measured for selected items which had appeared in the context of a continuous passage of text. It was expected that frequency of recall would be related, under both conditions of learning, to the degree to which the critical items were determined by the cumulative verbal context of the passage.

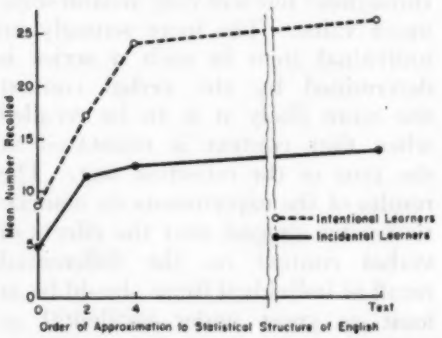

FIG. 1. Mean number of items recalled as a function of instructions and order of approximation.

EXPERIMENT I

Method

Materials. The learning materials consisted of 50-word lists prepared by Miller and Selfridge (1950) in a study of the effects of verbal context on recall. The lists used in the present experiment represented four different orders of approximation to the statistical structure of English: zero order, second order, fourth order, and continuous text. The zero order represents a random arrangement of words drawn from the Thorndike-Lorge word lists. The higher orders were generated by requiring *Ss* to complete word sequences of different lengths and linking together the sequences produced by different *Ss*. For the second order, the choice of each word was determined by only one preceding word; for the fourth order, each word was obtained in the context of three preceding words. The textual passages were taken directly from current books.

At each order there were two different lists which were used equally often.[2] The lists were recorded, with the words read one by one in a near monotone at a 2-sec. rate. Thus, the sequential links between successive items were not emphasized in the presentation and had to be discovered by *S*.

Procedure. Each list was learned by two different groups of *Ss*, one intentional and one incidental. Incidental *Ss* were given the assignment to rate the speaker's voice on a number of characteristics (calmness, authoritativeness, naturalness, and cheerfulness). The *Ss* were instructed to listen to the entire list and to be prepared to make their ratings on a 5-point scale after the end of the recording. Intentional *Ss* were given the same assignment and were, in addition, instructed to memorize as many words as possible, without regard to the order of presentation.

A 5-min. test of free recall was given 30 sec. after the presentation of the list. The *Ss* were instructed to write down all the words they could remember, regardless of the order in which the items had appeared in the list. Since there were some recurrent words in each of the higher-order lists, all *Ss* were instructed to reproduce each word as often as they thought it had occurred in the list. The

[2] At each order of approximation, one of the lists was that published by Miller and Selfridge (1950, p. 184 f.). The second list, which had also been used in their study, was kindly furnished to us by G. A. Miller.

ratings of the speaker's voice were made after the end of the test of recall.

Subjects. With four orders of approximation and two kinds of instruction, the experimental design comprised eight conditions. There were 20 *Ss* in each condition. The *Ss* were undergraduate students at the University of California. The experiment was conducted with small groups averaging four in number. The *Ss* were assigned to the experimental conditions in rotation in the order of their appearance in the laboratory, with correction for equal *N*s at the end. On the basis of a postexperimental inquiry three incidental *Ss* who had anticipated a test of recall were discarded and replaced.

Results

Amount recalled. The number of words correctly reproduced determined *S*'s recall score. Since *S*s had been instructed to reproduce recurrent items in accordance with their frequency in the list, repeated reproductions of such items were given credit up to the number of actual occurrences in the list. Prior to the over-all analysis the two lists used at each order of approximation were compared. At the zero and second orders of approximation the two lists were found to differ significantly in difficulty; at the two higher orders there were only small differences between the lists. There were, however, no inversions between successive orders. The differences between intentional and incidental learners were consistent from list to list at all orders of approximation.

The mean numbers of items recalled by the different groups are shown in Fig. 1. For intentional learners, recall increases as a negatively accelerated function of the order of approximation. These results agree closely with the findings of Miller and Selfridge (1950), with respect to both the general form of the functional relationship and the absolute level of recall. The curve for incidental learners also shows an initial rise but flattens out earlier than that for the intentional learners. The significance of the differences among the experimental groups was tested by an analysis of variance. Since there was significant heterogeneity of variance, the recall scores were subjected to a Freeman-Tukey square root transformation (Mosteller & Bush, 1954, p. 326 f.) prior to analysis. Both of the main effects are highly significant. For Order of Approximation, $F = 43.54$ ($df = 3$ and 152, $P < .001$); for Instructions, $F = 80.08$ ($df = 1$ and 152, $P < .001$). The interaction, Order of Approximation × Instructions, is also significant ($F = 3.12$, $df = 3$ and 152, $.01 < P < .05$), i.e., there is a reliable divergence between the two kinds of learners as a function of the order of approximation.

Amount recalled increases directly with the order of approximation. Progressive increases in the degree of contextual determination are, however, less beneficial under incidental than under intentional conditions. The negative acceleration of the recall function for both kinds of learners indicates that verbatim recall of a series depends primarily on short-range dependencies rather than on the meaning of the entire passage (cf. Miller & Selfridge, 1950, p. 183). A point is reached beyond which increases in contextual constraint yield diminishing returns. This point is reached earlier for incidental than for intentional learners. The length of contextually determined sequences to which *Ss* are likely to respond increases with instructions to learn.

Associative clustering at recall. Additional evidence for the differential effects of context under intentional and incidental conditions comes from an analysis of the sequential

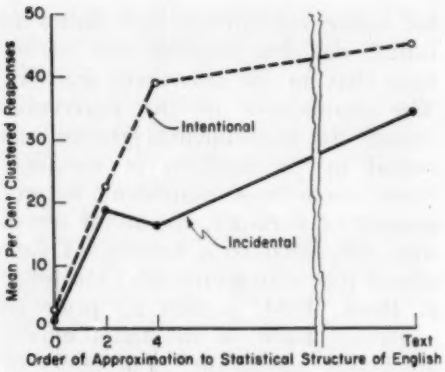

FIG. 2. Mean percentages of clustered responses as a function of instructions and order of approximation.

order in which items were reproduced in recall. Even though the recall instructions permitted *S*s to disregard order, there were many cases in which groups of words were reproduced exactly in the same sequence in which they had appeared in the list. To measure the degree of sequential clustering in recall, the number of items written down in correct sequences of two or more was determined for each *S* and converted into a percentage of his total recall score. Thus, items were scored as clustered if they were adjacent *and* were reproduced sequentially by *S*. Clusters involving recurrent words were included, but a given word was, of course, assigned to only one cluster. A clustered sequence was considered terminated by the intrusion of an error. The mean percentages of clustered responses are shown in Fig. 2. For intentional learners the percentage of clustered responses increases steadily with the order of approximation. Under incidental conditions the increases are neither as extensive nor as regular. Intentional learners give a larger percentage of clustered responses in the recall of all the higher-order lists. This difference is especially pronounced at the fourth order of approximation which represents a high degree of contextual determination and yet falls short of conformity to the conventional rules of sentence construction.

The question must be raised as to the extent to which the results shown in Fig. 2 merely reflect increasing probabilities of chance clusters correlated with rises in the total recall scores. Such an explanation appeared unlikely since the number of possible permutations grows at an extremely fast rate with increases in the total pool of items. Nevertheless, it was decided to apply an empirical correction for chance to the observed measures of clustering. Given a recall score of n items, n numbers between 1 and 50 were chosen in order from a table of random numbers. The percentage of clustered "responses" occurring in the random sequence was then determined according to the same rules as were applied to the actual recall protocols. This procedure was repeated for each of the 160 *S*s in the experiment. The percentages obtained by chance were uniformly low and showed little variation from condition to condition. For the intentional groups, the mean percentages at successively higher orders of approximation were 2.8, 1.8, 2.3, and 0.8. For the incidental groups, the corresponding values were 0.0, 1.0, 1.1, and 1.1. Whenever chance runs did occur, the appropriate percentage was subtracted from *S*'s observed percentage of clustered responses.

Following arc-sine transformation, the corrected percentage scores were subjected to an analysis of variance. Since the distributions at the lowest order of approximation were extremely skewed, heterogeneity of variance remained after the transformation.

The obtained levels of significance are quite high, however, and satisfy the stringent criteria that must be met in such a case (Lindquist, 1953, p. 86). For Order of Approximation, $F = 24.10$ ($df = 3$ and 152, $P < .001$), and for Instructions, $F = 9.48$ ($df = 1$ and 152, $.001 < P < .005$). The interaction of these variables is also significant ($F = 6.05$, $df = 3$ and 152, $P < .01$). When the groups learning the zero-order lists are omitted from the analysis, significant heterogeneity of variance is eliminated. In the reduced analysis both of the main effects remain significant beyond the .01 level. The F ratios are 11.56 ($df = 1$ and 114) and 5.20 ($df = 2$ and 114) for Instructions and Order of Approximation, respectively. The interaction, however, now fails to reach significance ($F = 1.65$). The significant interaction obtained in the first analysis must, therefore, be interpreted with caution.

In a study using lists of different orders of approximation, Deese and Kaufman (1957) found that the correlation between order of recall and position in the original list increased as the characteristics of textual English were approached. The trends in the percentages of clustered responses are consistent with these findings. The *Ss* in the present experiment were explicitly instructed to disregard serial order, and the cluster scores are independent of the particular point in the list at which *S* began his reproductions. Thus, the scores reflect correspondences between serial order in learning and order of response wherever they occurred in the course of recall. Such correspondences are present in the records of both kinds of learners, but they reflect the sequential dependencies in the list more clearly under intentional than incidental conditions.

Errors at recall. Table 1 shows the mean numbers of incorrect responses given by the various groups. Under both conditions of learning errors are considerably less frequent at the zero order than at the higher orders of approximation. The rise in errors as a function of the order of approximation is more gradual and regular for the incidental than for the intentional groups. Analysis of variance (after a Freeman-Tukey square root transformation to remove heterogeneity of variance) shows that the number of errors changes significantly with the order of approximation ($F = 6.56$, $df = 3$ and 152, $P < .01$). The difference between intentional and incidental learners is not significant nor is the interaction of order of approximation with instructions ($F < 1$ in both cases).

Incorrect responses as well as correct reproductions tend to increase with the order of approximation. Many of the errors could be identified as synonyms or associates of items in the list and may be attributed to interferences from *Ss'* language habits. Presentation of the items in familiar verbal contexts (*a*) permits the transfer of well established verbal habits to the recall of the experimental list, and (*b*) favors the intrusion of incorrect responses associated with these contexts through linguistic

TABLE 1

MEAN NUMBER OF ERRORS AT RECALL AS A FUNCTION OF INSTRUCTIONS AND ORDER OF APPROXIMATION

Order of Approximation	Intentional		Incidental	
	Mean	*SD*	Mean	*SD*
Zero	2.30	2.00	2.75	2.77
Second	6.10	6.17	4.05	4.20
Fourth	5.05	3.23	4.80	6.00
Text	6.65	4.91	6.30	3.64

usage. Hence both amount of recall and number of errors are positively related to order of approximation. At all orders of approximation but the lowest, intentional learners make more errors than the incidental learners although the difference is not significant. The trend is consistent, however, with the findings of earlier studies that instructions to learn enhance the probability of both correct and incorrect intraserial associations (Postman & Adams, 1957).

Experiment II

Method

Procedure. In the first part of the experiment the "cloze" procedure, developed by Taylor (1953), was used. In this procedure *Ss* are presented with a textual passage from which a number of words have been deleted and are required to fill in the missing words. In the present study, a 214-word passage from Julian Huxley's *Man Stands Alone* was used in the cloze procedure. This passage is reproduced in Flesch (1951, p. 16)[3] and was one of those used by Taylor in the development of the cloze technique. Thirty-five words were deleted from the passage. The average separation between successive blanks was 5.0 words, with an *SD* of 1.34. Proper names, articles, pronouns, prepositions, and conjunctions were not deleted. The passage was reproduced on 8.5 × 11-in. sheets and presented to *Ss* in 13 separate units. Each unit consisted of a sentence or independent clause, which served to facilitate contextual determination of *Ss*' responses. Thus, there was some variation from unit to unit with respect to both the number of words and the number of blanks. The durations of exposure for successive units were designed to allow *Ss* to move from blank to blank without delay or interruption. On the basis of preliminary tests the following schedule of exposures was developed: 11 units were exposed for .75 min. each, one unit for 1.25 min., and one unit for 1.75 min. During the exposures, the *Ss* used a cardboard strip with a window cutout to cover all the units except the one on which they were working. The *Ss* shifted the exposure window from one unit to the next at a signal from *E*. The instructions urged *Ss* to fill in all the blanks even if they were not confident about some of their responses.

The cloze procedure was administered to an intentional and an incidental group. The intentional *Ss* were instructed to try to remember the words which they used to fill in the blanks, without regard to the order of occurrence in the passage. No learning instructions were given to the incidental *Ss*. Thirty seconds after the end of the cloze procedure, a 5-min. test of free recall was given. The *Ss* were instructed to write down the words which they had used to fill in the blanks, in any order that occurred to them.

Subjects. There were 50 intentional and 50 incidental *Ss*. The procedure was administered to small groups of *Ss* averaging three in number. The *Ss* were assigned to the two conditions in rotation in the order of their appearance in the laboratory, with correction for equal *N*s at the end. Fifteen intentional and 12 incidental *Ss* were discarded and replaced because of failure to fill in all the blanks. One additional incidental *S* was discarded and replaced because of failure to follow instructions.

Results

Cloze scores. The number of blanks filled in correctly defines *S*'s cloze score. The mean cloze score of the Intentional Group was 8.32, with an *SD* of 2.46; for the Incidental Group the mean score was 8.08, with an *SD* of 1.74. The difference between the means does not approach significance ($t = .54$). The distributions of correct completions over blanks were virtually identical under the two conditions. The rank order correlation between the numbers of correct completions is .96.

Contextual determination of responses. The number of correct completions varied widely from blank to blank. These variations reflect differences in the degree of contextual constraint upon *Ss*' responses. The number of exactly correct completions does not, however, provide a maximally sensitive index of the degree

[3] The last sentence (19 words) in the 233-word passage reproduced in Flesch's book was omitted.

of contextual determination of responses to any given blank. Many of the incorrect responses were synonyms of the words used in the original passage or could be considered adequate alternatives to the expressions in the text. For this reason the extent of agreement among *S*s, independently of verbatim correspondence with the text, was used as a measure of the degree of contextual determination of the responses to a given blank. For each blank the degree of commonality of responses was determined by comparing each *S*'s response with that of all other *S*s and expressing the frequency of agreements as a proportion of the total number of comparisons. Thus,

$$C = \frac{A}{N(N-1)/2}$$

where C is the index of commonality, A is the number of agreements, and N is the number of *S*s. The index can vary between 0 and 1. The distribution of the values of C was positively skewed. For the Intentional Group the median C is .19, with a Q of .15; for the Incidental Group the median is .18 and Q is again .15. The distributions of commonality scores obtained under the two conditions are quite similar and there is close correspondence from blank to blank. The rank order correlation between the values of C is .86.

Frequency of usage of completion responses. The words supplied by intentional and incidental *S*s were also quite similar with respect to their frequencies of usage. The Lorge Magazine Count (Thorndike & Lorge, 1944) was used to estimate the frequency of usage of each completion response. The mean log frequency of *S*s' responses was then determined for each blank. For the Intentional Group, the grand mean is 2.81, and the *SD* of the blank means is .48. For the Incidental Group, the corresponding values are 2.80 and .46. As the grand means indicate, words of high frequency of usage were favored by both groups. Again, there is close correspondence between the groups from blank to blank. The rank order correlation between the mean log frequencies of usage by blank is .94. In general, the specific words used by intentional and incidental *S*s to fill in each blank overlapped closely. Even when there was some variation in the number of times each word was used, the values of C and the mean log frequencies of usage remained quite similar.

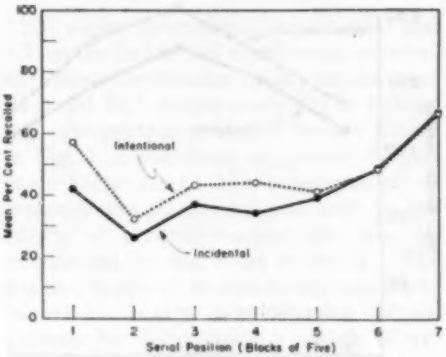

FIG. 3. Percentages of *S*s recalling their responses as a function of serial position, averaged for successive blocks of five.

Amount recalled. The mean number of responses recalled by the Intentional Group was 16.80, with an *SD* of 3.77. For the Incidental Group the mean recall score was 15.32, with an *SD* of 3.71. The difference between the two groups is significant ($t = 1.97$, $df = 98$, $.02 < P < .05$).

Figure 3 shows amount recalled as a function of the serial position of the blanks, averaged for successive blocks of five. For purposes of this plot, responses which were given by the same *S* more than once were omitted. If such a response is re-

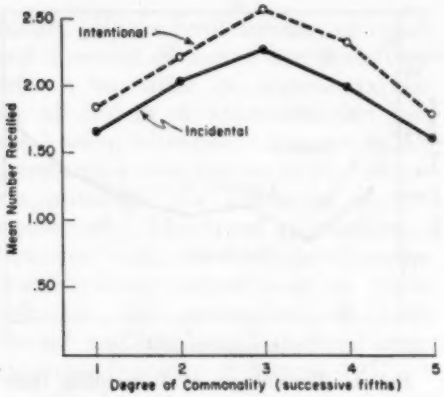

FIG. 4. Mean recall scores as a function of instructions and degree of commonality of responses.

produced only once, its serial position is indeterminate. Such cases occurred with approximately equal frequency under intentional and incidental conditions—the percentage of duplicate responses was 6.5 for the Intentional Group and 7.0 for the Incidental Group. Thus, the omission of duplicate responses does not influence the serial position trends. To adjust for minor variations in frequency of recurrent responses, the figure shows percentages rather than absolute numbers of recalls. In agreement with the results of earlier studies (Postman & Phillips, 1954; Postman & Adams, 1957), the curve for incidental learners shows less of a primacy effect and a relatively greater recency effect than that for intentional learners. The advantage of the intentional group is, therefore, limited to the beginning and middle of the series. The analysis of Deese and Kaufman (1957) suggests that primacy effects in free recall reflect the presence of sequential associations. The difference between the serial position curves of intentional and incidental learners indicates that instructions to learn favored the establishment of sequential associations between responses to successive blanks.

Recall as a function of contextual determination. For purposes of assessing the relation between contextual determination and recall, the blanks were rank ordered with respect to the commonality of *Ss*' responses. The rank order was based on the means of the indices of commonality for the intentional and the incidental group. In order to minimize differential effects of serial position, Blanks 1–5 and 31–35 were omitted from this analysis. As Fig. 3 shows, there are moderate rises in the serial position curves between Positions 6 and 30. Within these limits, however, there was no relationship between serial position and degree of commonality (rho = .11). There was also no relationship between degree of commonality and the mean log frequency of usage of *Ss*' responses (rho = .11). The 25 blanks included in the analysis were divided into five blocks of five each, in ascending order of degree of commonality. The mean number of responses recalled from each of these blocks is shown in Fig. 4. As the degree of contextual determination increases, amount recalled rises to a peak and then declines at the highest levels of commonality. The trends for the intentional and the incidental group are quite similar. Analysis of variance shows that the differences as a function of degree of commonality are significant ($F = 8.66$, $df = 4$ and 392, $P < .01$). With the early part of the series left out, the over-all difference between the two kinds of learners falls short of significance ($F = 2.77$, $df = 1$ and 98, $.05 < P < .10$). The interaction of instructions with degree of commonality is also not significant ($F < 1$), i.e., variations in contextual constraint

have parallel effects on recall under the two conditions.

The results shown in Fig. 4 are only in partial agreement with the original prediction. The initial rises in recall as a function of commonality support the expectation that increases in the degree of contextual determination favor retention. The decline at the highest levels of commonality was not predicted but becomes understandable when we consider the conditions which are responsible for variations in the degree of commonality. Two sources of constraint on *Ss*' responses may be distinguished: (*a*) the general context of the passage, and (*b*) the local context. The general context is provided by the content of the passage to which *Ss* have been exposed prior to a given blank. Local context refers to the constraints upon *Ss*' responses which stem from the specific words or phrases immediately preceding and following the blank. The relative weight of these two sources of constraint varies from blank to blank. When well established language habits are involved, local context alone can give rise to a high degree of commonality of responses. In fact, a high degree of agreement on one specific word is likely to be more heavily determined by the local than the general context. For example, three of the five blanks yielding the highest commonalities of response required the completion of a conventional phrase which is independent of the general context of the passage: holds *true;* having *been;* first *time.* In these examples the italicized word is the dominant completion response which was used by *Ss* with virtual unanimity. At the time of free recall, the general context of the passage may be assumed to persist, but specific local contexts are not reinstated. Hence the probability of recall will be directly related to the degree to which the original response was determined by the general context. Recall of responses determined primarily by the local context is likely to be low. The mean frequency of recall for the three items mentioned above was 12.3 under intentional conditions and 6.7 under incidental conditions, whereas the mean frequencies for all blanks were 24.0 and 21.7, respectively. The following interpretation of the trends shown in Fig. 4 is, therefore, suggested. Moderate increases in the commonality of response are attributed primarily to the effects of general context and are accompanied by increases in recall. The highest levels of commonality are likely to reflect heavy determination of responses by local context which is unfavorable to recall. These relationships obtain under both intentional and incidental conditions.

The significance attributed to the general context of the passage may appear to be inconsistent with the finding in Exp. I that recall for the textual passage was little better than for the fourth-order list. The difference between the conditions under which the learning materials were presented in the two experiments may be responsible for this apparent discrepancy. In Exp. I the words in the list were read in a near monotone and presented one by one at a 2-sec. rate. Thus, syntactical units were not differentiated and had to be discovered by *S* in the course of a continuous presentation of individual words. These conditions are not favorable to the cumulative establishment of a general context, and it is likely that only medium-range dependencies were effective during the presentation of the textual passage. In Exp. II, on the other hand, *Ss* were presented with complete sentences and clauses and were required to fill in the deletions in a manner consistent with the continuity of the narrative. It is reasonable to assume that the latter conditions are highly favorable to the establishment of a general context. This assumption is confirmed by the results of a postexperimental inquiry in Exp. II in which *Ss* were required to state whether they used their knowledge of the general content of the paragraph to help them recall the individual words. Ninety-two per cent of the intentional *Ss* and 90% of the incidental *Ss* replied in the affirmative. The fact that inten-

tional and incidental *Ss* appear to have been equally sensitive to the general context helps to account for the relatively small difference in the amount recalled by the two kinds of learners. When the materials evoke strong differential responses even in the absence of learning instructions the difference between intentional and incidental *Ss* is likely to be small (Postman, Adams, & Phillips, 1955).

Recall as a function of frequency of usage. The fact that parts of conventional phrases are recalled infrequently suggests that retention should be poor for any item that is likely to appear in a variety of contexts. Words that are used repeatedly in different contexts usually lack the distinctive connotations that favor strong association with any one context. This interpretation can be checked by an examination of the relationship between the probability of recall and the frequency of usage of *Ss'* responses. The higher the frequency of usage of a word the more numerous and varied are the contexts in which it is likely to occur. The present analysis would, therefore, lead us to expect an inverse relationship between the mean frequency of usage of *Ss'* responses and the number of recalls.

For Positions 6 through 30 the mean frequency of usage of *Ss'* responses was largely independent not only of the degree of commonality but also of serial position (rho = $-.18$ and $-.14$ for the intentional and incidental group, respectively). A rank order correlation was used, therefore, to assess the relationship between mean frequency of usage and recall. For the Intentional Group, the correlation is $-.44$ ($.02 < P < .05$); for the Incidental Group the correlation is $-.51$ ($P < .01$). Under both conditions of learning recall decreases as a function of the frequency of usage of the responses.

Errors at recall. The mean number of incorrect responses given by the Intentional Group on the test of recall was 1.78, with an *SD* of 1.52. For the Incidental Group the mean number was 1.36, with an *SD* of 1.32. The difference between the two groups is not significant ($t = 1.52$). A considerable proportion of the errors—43.3% for the intentional *Ss* and 41.2% for the incidental *Ss*—were words from the textual passage. Many of the remaining errors appeared to be synonyms or associates of *Ss'* responses to the blanks. As in Exp. I, instructions to learn increase the amount recalled without reducing the number of errors. Whatever difference there is points to a positive relationship between amount of recall and the number of overt errors. Thus, instructions to learn again appear to favor the formation of both correct and incorrect associations.

Discussion

The experiments have shown that degree of contextual determination significantly influences recall under both intentional and incidental conditions. Whether or not variations in verbal context interact with the conditions of learning depends on the operations used to measure the effects of contextual determination.

In Exp. I the learning materials consisted of lists which differed widely in the average degree of dependent probability between successive items. The *Ss'* task was to reproduce a list of items that had been presented serially. The intentional *Ss'* greater sensitivity to verbal context was reflected not only in the amount recalled but also in the degree of associative clustering at recall. While the incidental *Ss* also discriminated and reproduced contextually de-

termined sequences, they did so neither as consistently nor as systematically as the intentional learners. Thus, when degree of verbal context is defined as the average dependent probability betweeen the members of a series, it interacts significantly with the conditions of learning. These differential effects of context agree with the results of earlier studies showing that intentional learning is more favorable to the formation of intraserial associations than is incidental learning. When the order of approximation to the statistical structure of English is varied systematically, this difference between the two kinds of learners is brought into clear relief.

Experiment II was concerned with the selective recall of individual responses which had occurred in the context of a continuous passage. The conditions of Exp. II differed from those of Exp. I in two important respects: (*a*) the items which *S*s were required to recall had not formed a series but were scattered throughout the passage; (*b*) *S*s recalled their own responses to the blanks in the passage rather than items prescribed by *E*. In Exp. II degree of context refers, therefore, to variations in dependent probability for selected responses within a list rather than to average differences between lists. Under these conditions frequency of recall depends on the strength of association between specific items and the general context established by the content of the passage. The general context persists at the time of recall and serves to mediate the reproduction of individual items. Responses determined primarily by the local context and parts of conventional phrases unrelated to the general context have a low probability of being recalled. Selective recall of items associated with the general context occurs under both intentional and incidental conditions. The nature of the orienting task insured the establishment of the general context for both groups of *S*s. Hence, variations in the degree of contextual determination produced parallel effects on the probability of recall under intentional and incidental conditions.

Summary

Two studies were reported in which the effects of verbal context on intentional and incidental learning were investigated. In Exp. I intentional and incidental learners were exposed to lists of words representing four orders of approximation to the statistical structure of English. Under both conditions amount retained increased as a negatively accelerated function of the order of approximation to English. The rate of increase was, however, considerably greater for intentional than for incidental learners. The sequence of items in recall reflected contextual dependencies more closely under intentional than under incidental conditions.

In Exp. II recall was tested for selected responses which had been given in the context of a continuous passage of text. Intentional and incidental *S*s filled in the blanks in a passage from which approximately every fifth word had been deleted. Intentional learners recalled more of their own responses than did incidental learners. The degree of agreement among *S*s was used to estimate the amount of contextual constraint on the responses to different blanks. For both groups, the relationship between contextual constraint and recall was curvilinear. Recall was low when contextual constraint was minimal or when the response was part of a conventional phrase. Moderate increases in the commonality of response, which were attributed to the effects of the general context of the passage, were accompanied by increases in the probability of recall.

When verbal context refers to the average dependent probability among the members of a series, increases in the degree of contextual determination are more beneficial under intentional than under incidental conditions. Selective recall of individual items strongly associated with a continuous verbal context occurs under both conditions of learning.

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THE MAGNITUDE OF THE PULFRICH STEREOPHENOMENON AS A FUNCTION OF TARGET VELOCITY [1]

ALFRED LIT [2]

Vision Research Laboratories, University of Michigan

The present experiment deals with a stereoscopic effect that arises whenever a transversely moving object is viewed under conditions of unequal binocular retinal illuminance. The depth effect was first described and analyzed by Pulfrich (1922) and now bears his name. The stereophenomenon can be simply demonstrated by means of a pendulum-bob that is made to oscillate in a frontoparallel plane and on a level with *O*'s eyes. A small target for binocular fixation is positioned in his vertical median plane, directly below the oscillating bob and midway between the end-points of its swing. If a neutral or colored filter is placed in front of one of the eyes while the pendulum-bob is in motion, the bob will appear to rotate out of its plane of oscillation in a horizontal elliptical path that locates the bob nearer than it really is for one direction of stroke, and farther than it really is for the return stroke. The oscillating bob appears to rotate in a clockwise direction (as viewed from above) when the filter is placed before the left eye, and counterclockwise when the filter is placed before the right eye. The stereoeffect becomes noticeable at some threshold difference in binocular retinal illuminance and progressively increases in magnitude as the difference in binocular retinal illuminance is increased.

The explanation of the stereophenomenon given by Pulfrich (1922) is based on a suggestion by Fertsch that increasing differences in binocular retinal illuminance produce increasing differences in the hypothesized visual latent periods of the two eyes. For either eye, the magnitude of the visual latent period (that is, the magnitude of the hypothesized time delay between the onset of stimulation of any given retinal point in the eye and the arousal of the visual effect that signals the position of the stimulus target in space) is assumed to be a reciprocal function of the prevailing level of retinal illuminance. Hence, for any specified position of the moving target in the frontoparallel plane, the delay in the signal from the given stimulated retinal point in the covered eye will be slightly greater than the signal delay from the simultaneously stimulated corresponding retinal point in the uncovered eye. It must be further assumed that the binocular spatial localization of the moving target, at any given moment, is determined by the given pair of retinal points in the two eyes that yields simultaneously aroused binocular signals. Accordingly, to yield simultaneously aroused binocular signals from corresponding retinal points, the onset of stimulation for the eye that is covered by the filter must occur when the moving target is at a position farther behind in its path than the

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[2] Now with Bendix Systems Division, Ann Arbor, Michigan.

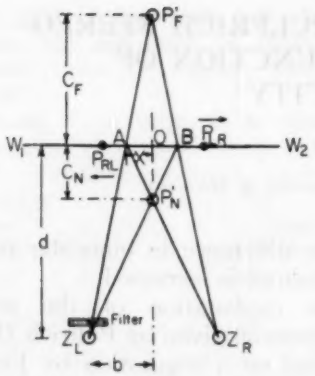

FIG. 1. Geometrical representation of the Pulfrich stereophenomenon indicating the stereoscopic space-image in the horizontal plane of fixation.

position at which the onset of stimulation occurs for the uncovered eye. Thus, simultaneously aroused binocular signals for the transversely moving target are provided by successive pairs of noncorresponding retinal points in the two eyes, and the magnitude of the stereoscopic effect theoretically depends on the amount of the retinal disparity produced as a consequence of the difference in the visual latent periods of the two eyes.

An understanding of the geometric relations involved in the stereophenomenon may be obtained with the aid of Fig. 1. The geometric analysis considers the case of a target that is oscillating in a frontoparallel plane with constant linear velocity, V. The oscillating target is placed at eye level in a frontal plane located at a distance d from the midpoint of the line Z_LZ_R which joins the centers of rotation of the two eyes. The linear path of the target in its plane of oscillation is denoted by W_1W_2. As indicated, the filter is placed in front of the left eye.

Figure 1 is meant to represent the stereoscopic space-image in the horizontal plane of fixation for the case in which the oscillating target, P_{LR}, is moving from left to right, and for the case in which the oscillating target, now designated by P_{RL}, is moving from right to left. The points P'_N and P'_F represent the respective near and far positions at which the oscillating target is supposedly localized by O by use of a binocular fixation target movable in the vertical median plane. The distance OP'_N designates the magnitude of the near displacement, C_N. The distance OP'_F designates the magnitude of the far displacement, C_F.

In accordance with the laws of binocular space discrimination, lines of sight from each eye are drawn through the two respective points of target localization, P'_N and P'_F. The two points of target localization are assumed to have relative positions of depth in the median plane such that the lines of sight drawn through Point P'_N and the lines of sight drawn through Point P'_F intersect the line W_1W_2 at the same two points, A and B. The intersection points A and B theoretically mark the respective positions in the path of the oscillating target at which onset of stimulation occurred in each of the two eyes. Thus, when the target is moving from left to right and appears to be located at the far position, P'_F, the onset of stimulation for the right eye occurred when the target (now at P_{LR}) was located at Point B, and the onset of stimulation for the left eye covered by the filter occurred when the target was located at Point A, a bit farther behind in its path. The time taken for the target to move from B to P_{LR} represents the magnitude of the visual latent period of the right eye, and the time taken for the target to move from A to P_{LR} represents the slightly larger magnitude of the visual latent period of the left eye. Consequently, the time taken for the target to move from A to B represents the difference, Δt_F, in the visual latent periods of the two eyes, based on the far position of target localization, P'_F. Since the velocity of the oscillating target is identical for either direction of movement, it follows by the same reasoning that when the target is moving from right to left and appears to be located at the near position, P'_N, the onset of stimulation for the right eye occurred when the target (now at P_{RL}) was located at Point A, and the onset of stimulation for the left eye covered by the filter occurred when the target was located at Point B, a bit further behind in its path. In this case, the time taken for the target to move from B to A represents the difference, Δt_N, in the visual latent periods of the two eyes, based on the near position of target localization, P'_N. It should be noted that the latency differences based on the near and the far positions of target localization are theoretically equal in magnitude, that is, $\Delta t_N = \Delta t_F$.

If, for any given difference in binocular retinal illuminance, the magnitude of the near and far displacements, C_N and C_F, are

experimentally determined, it is possible to calculate the magnitude of the corresponding near and far latency differences, Δt_N and Δt_F, if the linear velocity, V, of the oscillating target is known.

It can be readily seen from similar triangles in Fig. 1 that for target localizations at P'_N and P'_F, respectively,

$$X = bC_N/(d - C_N)$$

and

$$X = bC_F/(d + C_F) \qquad [1]$$

where $X = \frac{1}{2}$ the distance from A to B and $b = \frac{1}{2}$ the distance between the centers of rotation of the two eyes. The distance of the plane of oscillation, d, and the near and far displacements, C_N and C_F, have been previously defined.

For an oscillating target moving with constant linear velocity, V, the time taken for the target to pass through the distance X is given by the formula,

$$t = \frac{X}{V} \qquad [2]$$

The time taken for the target to move from A to B (or B to A) represents the latency difference, Δt, between the two eyes. Since $\Delta t = 2t$, we obtain from Equation 2,

$$\Delta t = \frac{2X}{V} \qquad [3]$$

Substituting for X the respective expressions given in Equation 1, we finally obtain the following relationship between the experimentally determined near and far displacements (C_N and C_F) and the corresponding computed near and far latency differences (Δt_N and Δt_F):

$$\Delta t_N = \frac{2b}{V} \cdot \frac{C_N}{d - C_N}$$

and

$$\Delta t_F = \frac{2b}{V} \cdot \frac{C_F}{d + C_F} \qquad [4]$$

It should be noted from purely geometric considerations that, for any constant difference in binocular retinal illuminance, the magnitude of the stereoscopic effect as measured by C_N and C_F should progressively increase as the linear velocity of the oscillating target is increased, but the corresponding calculated values of Δt_N and Δt_F should remain constant for all target velocities used.

The present experiment is a continuation of a research program (Lit, 1949; Lit & Hyman, 1951) designed to obtain systematic data on some of the important stimulus variables that influence the magnitude of the Pulfrich effect. The aim of the research program is to provide appropriate data that ultimately can be directly related to theories and data concerned with several basic visual functions: (*a*) binocular space discrimination, (*b*) the relationship between the magnitude of the monocular visual latent period and level of retinal illuminance, (*c*) intensity discrimination, (*d*) retinal interaction, and (*e*) color vision. In the present experiment, the effect of target velocity is systematically studied. This is an important variable whose effect on the magnitude of the stereoeffect (that is, on C_N and C_F) can be predicted on the basis of the geometrical theory of the Pulfrich effect. The present experiment thus provides a direct test of the adequacy of the proposed theory. It will also provide data that can be related to classical theory of binocular space discrimination and to theories concerned with retinal interaction effects of moving targets.

Apparatus and Procedure

A schematic representation of the apparatus[3] is presented in Fig. 2A. A detailed description is available in a previous report (Lit & Hyman, 1951). The apparatus consists of three major components: (*a*) the oscillating target, (*b*) the fixation target, and (*c*) the lighting and screening units.

The O is seated in a dark room (D) and binocularly observes the fixation target (FT) and the oscillating target (OT) through a pair of circular artificial pupils (E) that are 2.5 mm. in diameter and adjustable for interpupillary separation. The artificial pu-

[3] The apparatus was originally constructed at Pupin Laboratories, Columbia University, partially through funds from a research grant-in-aid generously provided by the American Academy of Optometry.

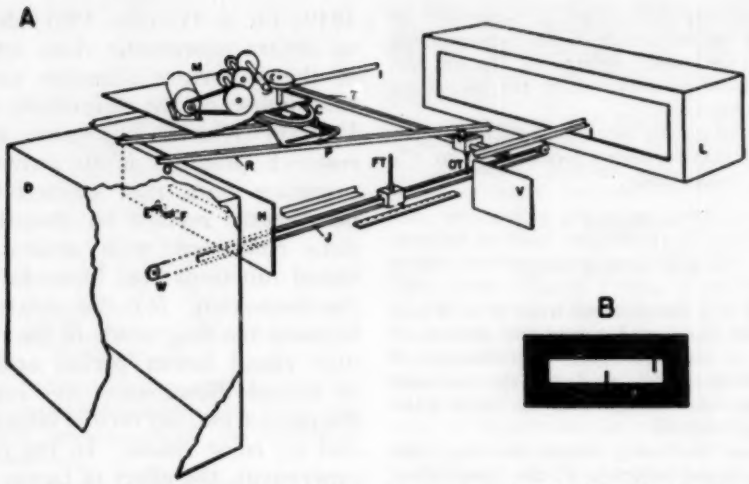

FIG. 2. Schematic representation of the apparatus and *O*'s view of stimulus targets. A. The *O* is seated in a dark room (*D*) and binocularly observes the fixation target (*FT*) located in the lower visual field and the oscillating target (*OT*) located in the upper visual field through a pair of artificial pupils (*E*). Movement of the oscillating target in a fronto-parallel plane 100 cm. from *O*'s eyes can be varied over a wide range of constant linear velocities. The fixation target in *O*'s vertical median plane can be moved either toward or away from his eyes by means of a pulley wheel (*W*) located in the dark room. Background illumination is provided by a lightbox (*L*). The retinal illuminance of each eye is controlled by neutral density filters placed in the pair of filter boxes (*F*). Horizontal (*H*) and vertical (*V*) screens provide a constant rectangular field of view. B. The upper rod is the oscillating target; the lower rod is the fixation target. (From Lit & Hyman, 1951.)

pils are attached to eye-tubes which are mounted on the inner wall of the dark room. In front of each eye-tube, a filter box (*F*) is mounted on the outer wall so that *E* can control the retinal illuminance of each eye by combinations of neutral density filters. The *O*'s head is kept immobilized by means of chin and forehead rests.

The oscillating target (*OT*) is a blackened steel rod ¼ in. in diameter. It is vertically suspended downward to eye level from a Jacobs chuck in which it is retained. The chuck is centrally mounted on the under-surface of a supporting carriage which rides on horizontal tracks (*T*) located in a frontal plane at a distance of 100 cm. from *O*'s eyes. The carriage receives its movement from a horizontally oscillating drive-rod (*R*) which is pivoted at Position *O*, a point located in *O*'s median plane directly above the midpoint of the line joining the two eyes. Power for the drive-rod is provided by a cam-regulated mechanism (*C*) which converts constant angular velocity into reciprocating linear velocity, with the central 90% of stroke at constant speed. The power to the drive-rod is applied at a vertical pivot point (*P*) permanently mounted on the drive-rod. The electrically driven gear train (*M*) shown in Fig. 2A was replaced by a Zero-Max (Revco, Inc., Model 143) variable speed transmission device to allow adjustments of the linear velocity of the oscillating target over a wide range of values. Calibration of the transmission device was achieved by measuring the time required for the supporting carriage of the oscillating target to move through a fixed distance of 10 cm. in the central region of the elevated tracks (*T*) on which it rides. The time measurements were performed with an Electronic Precision Chronoscope (Wichita Apparatus Supply, Inc., Model 251). Thus, the linear velocity of the oscillating target is specified for all positions of the lever arm of the speed control link.

The fixation target (*FT*) is a blackened steel rod ¼ in. in diameter. It is held vertically upright to eye level in a Jacobs chuck that is mounted on the upper surface of a supporting carriage located below eye level. The comparison rod and its supporting carriage are movable along a horizontal metal track (*J*) located in *O*'s vertical median

plane. By means of a pulley wheel (W) located in the dark room, O can adjust the position of the fixation target in a direction either towards or away from his eyes. The distance of the fixation target from O's eyes, as measured along the metal track, can be read by E from a scale calibrated in millimeters. The use of a vernier index permits E to estimate the distance of the fixation target to within 0.01 cm. The height of the upper end of the fixation target is set on a level with O's eyes. Thus, when the oscillating target is at a position directly above the fixation target, the targets appear contiguous in O's vertical median plane. At this distance (100 cm.) from O's eyes, the diameter of each rod subtends a visual angle of 10.9 minutes of arc.

Uniform background illumination is provided by ten 150-w. frosted lamps that are appropriately mounted in an asbestos lined, galvanized iron lightbox (L). The lightbox is located in a frontal plane 250 cm. from O's eyes. Lamp voltage is maintained constant (to within $\pm 1.0\%$) at 124 v. AC by means of an automatic constant-voltage output regulator. The illuminated surface is a white matte screen that is attached to the inner rear wall of the lightbox. The surface has a luminance of 854 ft.-L. as measured with a Macbeth illuminometer. The color temperature at the given voltage is 2735° K. With the 2.5-mm. artificial pupil in use, the retinal illuminance without filters is 14359 trolands or 4.16 log trolands. The field of view in the vertical direction is kept constant at 4.2° by a horizontal slit (26 cm. × 1.5 cm.) cut at eye level in a black vertical screen (H) located 21 cm. in front of O. The field of view in the horizontal direction is kept constant at 21.6° by means of a pair of vertical screens (V) (only one screen is shown in Fig. 2A) adjusted symmetrically in the plane of the oscillating target, 0.5° beyond the end-points of its reciprocating stroke. The view of the targets as seen by O is shown in Fig. 2B.

Two trained graduate students who were emmetropic served as paid Os. The monocular visual acuity of each O was better than 20/20, and the ductions of each were normal at both distance and near. At a fixation distance of 100 cm., the interpupillary separation for Observer F. C. was 6.20 cm. and that for Observer M. M. was 6.70 cm. At this fixation distance, the phoria for Observer F. C. was 3^{Δ} exophoria and that for Observer M. M. was 1^{Δ} esophoria.

Daily practice sessions were held for a period of about a month during which Os were trained in the procedure of localizing the apparent near and far positions of the oscillating target at various target velocities and under different amounts of unequal binocular retinal illuminances, $\log(E_R/E_L)$. In performing his settings, O continuously fixates the upper end of the movable fixation rod and adjusts this rod in the vertical median plane until it appears to lie directly below the near and far paths of the oscillating target. The apparent near and far positions of the oscillating target are each localized first when the fixation rod is moved away, and again when it is moved toward O. In this way, multiple pairs of determinations of C_N and C_F can be obtained under any given set of viewing conditions. With filters of equal optical density in front of the eyes, only a single path of the oscillating target was reported; that is, no Pulfrich effect was elicited at any given velocity under conditions of equal binocular retinal illuminance.

Settings for the apparent near and far positions of the oscillating target were obtained from both Os at each of 11 target velocities, V: 2.59, 5.90, 8.16, 10.28, 13.76, 19.96, 26.86, 35.56, 45.01, 55.53, and 68.17 cm./sec. For target movement in a frontoparallel plane located 100 cm. from O's eyes, these values of linear velocity correspond to the following angular velocities: 1.49, 3.38, 4.68, 5.89, 7.88, 11.44, 15.39, 20.37, 25.78, 31.81, and 39.05 deg./sec. In a given experimental session only one target velocity was used and five pairs of settings (10 readings each for C_N and C_F) were obtained from each O for each of four conditions of increasing inequality of binocular retinal illuminance, $\log(E_R/E_L)$. The retinal illuminance of the left eye ($\log E_L$) was held constant at 2.06 log trolands by use of a neutral filter of optical density 2.10. The retinal illuminance of the right eye ($\log E_R$) was successively increased by use of neutral filters of optical densities 1.98, 1.52, 1.03, and 0.52. Thus, the four values of $\log (E_R/E_L)$ used at each of the 11 target velocities were: 0.12, 0.58, 1.07, and 1.58. A total of 22 experimental sessions was held for each O. A counterbalanced order was introduced for target velocity. That is, for the first 11 sessions the target velocity was presented in order of increasing magnitude, and for the second 11 sessions the target velocity was presented in decreasing order.

Results

The results for both Os are presented in Table 1. Each entry of

TABLE 1

DEPTH DISPLACEMENTS (IN CENTIMETERS) OBTAINED AT EACH OF 11 TARGET VELOCITIES UNDER FOUR CONDITIONS OF UNEQUAL BINOCULAR RETINAL ILLUMINANCE, LOG (E_R/E_L)

Target Velocity Cm. per Sec.)	log (E_R/E_L) = 0.12				log (E_R/E_L) = 0.58				log (E_R/E_L) = 1.07				log (E_R/E_L) = 1.58			
	F. C.		M. M.		F. C.		M. M.		F. C.		M. M.		F. C.		M. M.	
	C_N	C_F	C_N	C_F	C_N	C_F	C_N	C_F	C_N	C_F	C_N	C_F	C_N	C_F	C_N	C_F
2.59	0.13	0.20	0.33	0.39	0.48	0.46	0.63	0.59	0.74	0.75	0.85	0.82	0.95	0.98	1.07	1.03
5.90	0.27	0.19	0.44	0.42	0.80	0.70	0.85	0.94	1.28	1.16	1.37	1.35	1.63	1.48	1.93	1.93
8.16	0.41	0.27	0.35	0.62	1.12	0.97	1.09	1.22	1.55	1.48	1.67	1.63	1.99	1.90	2.17	2.27
10.28	0.54	0.21	0.49	0.70	1.43	1.07	1.26	1.50	2.05	1.68	2.04	2.18	2.45	2.14	2.49	2.77
13.76	0.83	0.38	0.61	1.01	1.91	1.36	1.58	1.88	2.57	2.09	2.42	2.77	3.08	2.79	3.24	3.45
19.96	1.31	0.19	0.61	1.29	2.69	1.61	2.15	2.64	3.52	2.73	3.30	3.76	4.12	3.45	3.74	4.99
26.86	2.01	0.82	0.72	1.67	3.54	2.23	2.67	3.60	4.64	3.24	3.74	5.18	5.98	4.54	4.80	6.38
35.56	2.58	0.57	0.87	2.23	4.77	2.21	2.42	4.21	6.07	3.49	4.52	6.74	7.41	5.27	5.77	8.88
45.01	3.15	0.58	0.97	2.01	5.45	2.50	3.43	4.64	7.32	4.33	5.37	7.85	9.08	6.35	6.82	9.48
55.53	3.72	0.05	0.77	2.79	6.62	2.13	4.41	6.63	8.93	3.73	6.88	9.45	10.70	6.21	8.42	12.33
68.17	4.22	0.02	0.60	5.70	7.50	1.45	4.46	9.89	10.66	3.46	7.64	13.30	12.57	5.95	9.40	15.74

Note.—The retinal illuminance of the left eye, log E_L, was kept constant at 2.06 log trolands. C_N and C_F refer, respectively, to the near and far displacements of a black vertical rod oscillating in a frontoparallel plane located 100 cm. from O's eyes. Each entry for the two Os (F. C. and M. M.) is based on the mean of 20 settings. The thickness of the stimulus target used was 0.125 in.

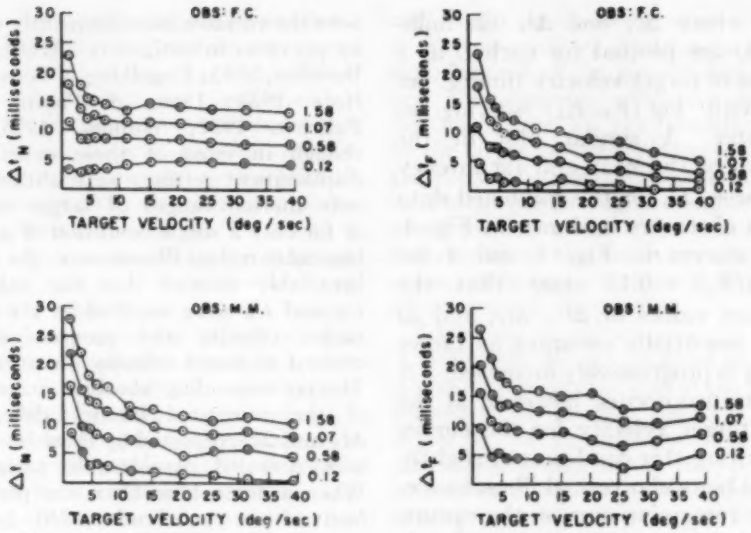

FIG. 3. Latency differences as a function of target velocity for four conditions of unequal binocular retinal illuminance. The latency differences (Δ_N and Δ_F) were computed from Equation 4 for the corresponding near and far displacements (C_N and C_F) given in Table 1. The number accompanying each curve represents the prevailing magnitude of log (E_R/E_L), where the retinal illuminance of the left eye, log E_L, is kept constant at 2.06 log trolands. Each point is based on the mean of 20 readings.

C_N and C_F represents the mean value (in centimeters) of two sets of 10 readings obtained at each target velocity under each of the four specified conditions of unequal binocular retinal illuminance.

Inspection of Table 1 reveals that, for any given value of log (E_R/E_L), C_N and C_F progressively increase as target velocity is increased. C_N and C_F also progressively increase as log (E_R/E_L) is increased at any given target velocity. A characteristic individual difference in performance should be noted: for Observer F. C. the values of C_N are consistently larger than the corresponding value of C_F; for Observer M. M., contrariwise, the values of C_N are consistently smaller than the corresponding values of C_F.

To facilitate analysis of these data in terms of the geometrical theory of the Pulfrich effect, the corresponding latency differences, Δt_N and Δt_F, have been computed from Equation 4 for each set of values of C_N and C_F given in Table 1. The results of the computation are shown graphically in

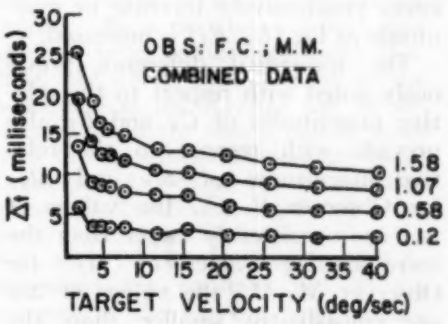

FIG. 4. Average latency difference as a function of target velocity for four conditions of unequal binocular retinal illuminance, log (E_R/E_L). The average latency differences, $\overline{\Delta t}$, were obtained by combining the values of Δt_N and Δt_F in Fig. 3 for both *O*s. Thus, each point is based on the mean of 40 readings.

Fig. 3 where Δt_N and Δt_F (in milliseconds) are plotted for each O as a function of target velocity (in deg. per sec.) with log (E_R/E_L) serving as parameter. A similar plot of the averages of the near and far latency differences, $\overline{\Delta t}$, for the combined data of both observers is shown in Fig. 4.

The curves in Fig. 3 and 4 for log $(E_R/E_L) = 0.12$ show that the computed values of Δt_N, Δt_F, and $\overline{\Delta t}$ remain essentially constant as target velocity is progressively increased. A slight upturn occurs, however, at the lowest target velocity for the curves representing this condition of slightly unequal binocular retinal illuminance. For the remaining curves, the upturn above their respective constant levels becomes more marked and occurs at progressively higher values of target velocity as the magnitude of inequality of binocular retinal illuminance is increased; for the curves representing log $(E_R/E_L) = 1.58$, the computed latency differences seem to be independent of target velocity for velocities greater than about 20 deg./sec. It is also to be noted from Fig. 3 and 4 that at any given target velocity the computed latency differences progressively increase in magnitude as log (E_R/E_L) is increased.

The individual difference previously noted with respect to the relative magnitudes of C_N and C_F also prevails with respect to the relative magnitudes of Δt_N and Δt_F: for Observer F. C., the values of Δt_N are consistently larger than the corresponding values of Δt_F; for Observer M. M., the values of Δt_N are consistently smaller than the corresponding values of Δt_F.

Discussion

Of all stimulus factors known to influence the magnitude of the Pulfrich stereophenomenon, target velocity has been the variable most frequently studied by previous investigators (Arndt, 1930; Banister, 1932; Engelking & Poos, 1924; Holz, 1934; Liang & Piéron, 1947; Pulfrich, 1922; Wölfflin, 1925). Although in most of these experiments displacement settings were obtained for only limited ranges of target velocity or for only a single condition of unequal binocular retinal illuminance, the results invariably showed that the values of C_N and C_F were smallest at the lowest target velocity and progressively increased as target velocity was increased. The corresponding absolute magnitudes of the computed latency differences, Δt_N and Δt_F, reported by these investigators, revealed considerable variability. When a dense blue filter was placed in front of one eye, Arndt (1930) found a computed latency difference of 1917 msec. for a target velocity of 0.04 deg. per sec. and a computed latency difference of 110 msec. for a target velocity of 6.67 deg. per sec. These data thus show a 17-fold decrease in latency difference as target velocity undergoes a 170-fold increase in magnitude. In contrast, the data of Holz (1934) revealed that, for a given blue filter, a computed latency difference of 97 msec. was obtained for a target velocity of 0.65 deg. per sec. and a computed latency difference of 16 msec. was obtained for a target velocity of 23.23 deg./sec. In this case, latency difference undergoes only about a 6-fold change. Holz also reported that the computed latency difference showed no further decrease in magnitude (below 16 msec.) as target velocity was respectively increased to values of 40.42 and 130.53 deg./sec.

The data of the present experiment (that is, the curves given in Fig. 4) seem to show better agreement with predictions based on the geometrical theory of the Pulfrich effect. For each of the specified differences of binocular retinal illuminance used, the respective magnitude of the computed average latency difference, $\overline{\Delta t}$, remains essentially constant as target velocity is systematically varied. Discrepancies appear pri-

marily at low target velocities, particularly for the experimental curves representing large values of log (E_R/E_L). These discrepancies reflect the fact that as target velocity is progressively decreased the values of C_N and C_F obtained for the given curve become systematically slightly larger than the respective theoretical values required by Equation 4 to yield a given constant $\overline{\Delta t}$ for all target velocities.

A similar discrepancy for low target velocities occurs in the so-called sensation–time (*Empfindungszeit*) experiments of Fröhlich (1923) in which a vertical slit of light is moved in a frontoparallel plane directly behind a horizontal opening in a screen. To O seated directly in front of the screen, the moving target typically does not appear to come into view at the entrance edge of the horizontal opening but rather at some small lateral distance within the border of the screen aperture. Fröhlich attributed this effect to the visual latent period (*die Empfindungszeit*). He proposed that the magnitude of the sensation–time for any given set of observation conditions could be computed from the time difference between the actual and seen appearance of the moving target, that is, sensation–time $= d/v$, where d is the lateral distance from the entrance edge at which the vertical target first appears to come into view and v is the linear velocity of the target in its frontoparallel path. Experiments on the effects of target velocity (e.g., Holz, 1934) yielded sensation–time vs. target velocity curves for various target luminances that also characteristically show an upturn at low target velocities. That is, as target velocity is progressively decreased, the respective lateral distances from the entrance edge at which the target is localized by O become progressively smaller but at a rate considerably slower than that required to yield a given constant computed sensation–time for all target velocities. Holz (1934) obtained sensation–time measures under stimulus conditions that were identical to those prevailing in his experiment on the Pulfrich effect, that is, target velocities and target luminances were identical in the two studies. His results showed that, for each of the given target velocities, the algebraic difference between the magnitude of the sensation–time for the target having the lower luminance and the magnitude of the sensation–time for the target having the higher luminance yielded a value that was numerically equal to the respective computed latency difference obtained in his experiment on the Pulfrich effect.

Additional experiments on the effects of target velocity are required to clarify the reasons for the upturns in the latency difference vs. target velocity curves of Fig. 4. Of particular interest in this connection would be the results of additional experiments in which the thickness of the oscillating target is systematically varied and in which specified differences of binocular retinal illuminances are produced at many basic levels of illuminance.

The present experiment also provides data on the effects of specified differences in binocular retinal illuminance on the magnitude of the near and far displacements and their corresponding computed latency differences. The data show that, for each of the given target velocities, displacements C_N and C_F and their corresponding calculated latency differences, Δt_N and Δt_F, progressively increase as log (E_R/E_L) is increased. As in the case of similar data obtained in an earlier experiment (Lit, 1949) the effects of variations in the magnitude of log (E_R/E_L) can be accounted for if the assumption is made that the hypothesized absolute visual latent period, t, is an inverse function of retinal illuminance, log E. A schematic representation of this relationship is shown in Fig. 5. In this figure, log E_L represents the constant retinal illuminance of the left eye, and log E_{R1}, log E_{R2}, and log E_{R3} represent the increased retinal illuminance successively produced in the right eye. It can be readily seen with the aid of Fig. 5 that the difference in absolute latency (Δt) theoretically increases as the difference in binocular retinal illuminance [log

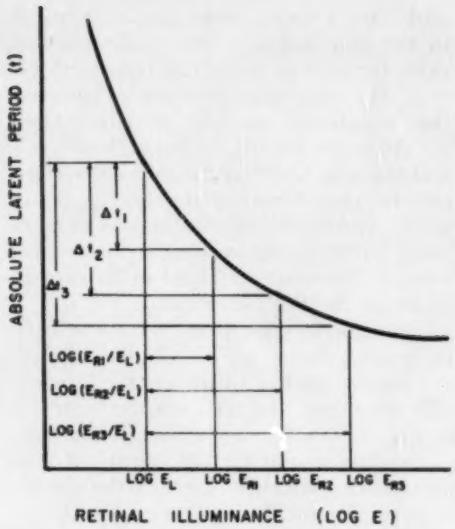

FIG. 5. The hypothesized absolute visual latent period (t) as a function of retinal illuminance (log E). The curve represents an assumed relationship proposed to account for the experimental fact that, for the given constant retinal illuminance of the left eye (log E_L), latency difference (Δt) increases progressively as the difference in binocular retinal illuminance [log (E_R/E_L)] is increased.

(E_R/E_L)] is increased. The specific rate of increase theoretically depends, of course, on the initial magnitude selected for the retinal illuminance of the left eye (log E_L).

When the data of the present experiment are plotted to show how $\overline{\Delta t}$ varies as a function of log (E_R/E_L), with target velocity serving as parameter, the obtained curves (not given here) are in quantitative agreement with predictions based on the analysis of Fig. 5. The curves do not, however, overlap nor show the same shape for all target velocities. The curves representing low target velocities (below 10 deg./sec.) are considerably displaced progressively upward on the ordinate axis. The curves show a relatively more rapid rise in $\overline{\Delta t}$ as log (E_R/E_L) is increased, an effect, of course, which reflects the lack of parallelism exhibited in the curves of Fig. 4.

From data obtained in an earlier experiment (Lit, 1949), it was possible to determine an empirical equation which describes the relationship existing between the hypothesized absolute visual latent period (t) and level of retinal illuminance (log E). The necessary computations were deferred pending the outcome of additional experiments concerned with evaluating the effects of systematic variations in distance of observation of the oscillating target, target velocity, and target thickness. It has since been established (Lit & Hyman, 1951) that latency difference is independent of distance of target oscillation. The present experiment demonstrates that, for small differences of binocular retinal illuminance, latency difference is independent of target velocity over a very wide range of velocities. The effects of systematic variations in target thickness will be studied next and the results reported separately.

Finally, mention should be made of the localization error that exists for the moving target when viewed under conditions of equal binocular retinal illuminance. For *O*s used in the previous experiments (Lit, 1949; Lit & Hyman, 1951) the oscillating target appeared to be moving in a frontoparallel plane located nearer than the plane defined by the "true" distance of the oscillating rod. The localization error occurred at all levels of equal retinal illuminance (Lit, 1949) and at all distances of observation (Lit & Hyman, 1951). A similar localization error occurred for *O*s used in the present experiment. At all target velocities, the oscillating target appeared nearer than the true plane of oscillation for Observer F. C. and farther than the true plane of oscillation for Observer M. M. It should be pointed out that the magnitude of the localization error for each *O* was insufficient to establish equality between the corresponding near and far computed latency differences. Thus, when the corresponding values of C_N and C_F were "corrected" for the localization error, it still turned out that $\Delta t_N > \Delta t_F$ for Observer F. C. and that $\Delta t_N < \Delta t_F$

for Observer M. M., particularly for the displacements produced by the larger differences of binocular retinal illuminance. In all cases, the computed average latency difference, $\overline{\Delta t}$, remained virtually unchanged when the respective values of Δt_N and Δt_F were each "corrected" for the localization error.

Summary

When filters of unequal optical density are placed in front of the two eyes, a target which is actually oscillating in a frontoparallel plane appears nearer than it really is for one direction of stroke and farther than it really is for the return stroke (Pulfrich stereophenomenon). Measurements of the near and far displacements of a black vertical rod have been obtained for a wide range of target velocities under each of several conditions of unequal binocular retinal illuminance.

The experimental data show that, for any given difference in binocular retinal illuminance, the near and far displacements progressively increase as target velocity is increased. The data show also that, for any given target velocity, the near and far displacements progressively increase as the difference in binocular retinal illuminance is increased.

The obtained results are analyzed in terms of an hypothesized absolute visual latent period whose magnitude is assumed to be an inverse function of level of retinal illuminance. The results are shown to be in good quantitative agreement with predictions based on the geometrical theory of the Pulfrich effect. Discrepancies at low target velocities are noted and discussed.

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EVIDENCE FOR A SELECTIVE PROCESS DURING PERCEPTION OF TACHISTOSCOPICALLY PRESENTED STIMULI [1]

JOHN BROWN

Birkbeck College, University of London

It has usually been found that, when a complex stimulus field is presented tachistoscopically, *S* will report features of the field specified in an instruction more accurately if the instruction is given immediately before rather than immediately after presentation (Vernon, 1952). From Külpe onwards it has usually been concluded that, when the instruction is given before presentation, a selective set is established which leads to more efficient perception. An alternative interpretation would be that the set has influenced not the perceptual process itself but the concurrent storage of the perceived information without which subsequent report could not take place: This will be considered further in the discussion.

For the moment we may confine ourselves to the question whether a selective process can operate *during* perception of a tachistoscopically presented stimulus field irrespective of whether it operates *within* perception. There are two reasons for being dissatisfied with the existing evidence. First, in certain recent experiments no evidence for a selective process during perception was obtained (Augenstine, Blank, Quastler, & Wayner, 1956; Lawrence & Coles, 1954; Lawrence & Laberge, 1956). Secondly, an inadequate experimental design has been employed. It has been the custom to make a simple comparison between the accuracy of report when the instruction immediately precedes presentation and the accuracy when it immediately follows presentation. Greater accuracy under the former condition has been assumed to reveal the operation of a selective process during perception. This is to overlook the possibility that differential effects during retention have been responsible for the increase in accuracy. When the instruction is given before presentation, *S* can make his report immediately and without interruption. When it follows presentation, however, *S* has to attend for it and perceive it before he can record his report. Moreover, any short gap between presentation and the arrival of the instruction will be a gap during which *S* will not know which features of the field to rehearse. Thus higher recall when the instruction comes before presentation might be due to more favorable retention conditions rather than to a selective process during perception, especially as there is evidence that retention in immediate memory is very easily disturbed (Brown, 1958).

In order to avoid differential effects during retention, a more elaborate experimental design is needed. The design adopted in the present experiment involves two instructions to *S* on each trial, the second of which is simultaneous with presentation of stimuli. A "critical" instruction told him what he was to attempt to report and a "neutral" instruction (i.e.

[1] The research reported in this paper was supported by a grant from the Central Research Fund, University of London.

neutral with respect to the perceptual process) told him on which side of an answer form he was to record his report. Under one condition the critical instruction was given simultaneously with presentation; under a second condition the order of the instructions was reversed. With this design an instruction is given at the time of presentation under both conditions and there is no interval between presentation and the arrival of the second instruction. Thus the design eliminates the opportunity for differential effects during retention and any difference between the conditions will be attributable to the presence or absence of a selective process during perception. A presupposition of the design is that it takes time to perceive the critical instruction and further time to establish the necessary set for a selective process to operate: otherwise, a selective process would be possible even when the critical instruction was simultaneous with perception.

METHOD

Two sets of stimuli were presented on each trial. The *S*'s task was to report the set specified in the critical instruction. Under Cond. I this instruction enabled *S* to select the required set on the basis of its class (digits versus consonants), position, and color. Under Cond. II the required set could be selected only by its class, under Cond. III only by its position, and under Cond. IV only by its color.

The eight stimuli for each trial were stenciled on to a white card and were arranged in two rows of four, one immediately below the other. The four outer stimuli, i.e., the stimuli at either end of the two rows, formed one set and the four inner stimuli formed the second set. Thus a fixation point in the center was appropriate whichever set of stimuli *S* was required to report. The stimuli (height 5 mm.) of each set were either all consonants or all digits (selected from the digits 0 to 9) and were either all red or all black. Under Cond. I, the outer set was black consonants and the inner set was red digits. The critical instruction was either "letters" or "digits" and determined for *S* which set he attempted to report. It will be seen that selection of the correct set was possible on the basis of its class, its position (outer or inner), or its color. Under Cond. II all the stimuli were black and two alternative arrangements were used equally often and in random order. In one arrangement the outer set was consonants, and the inner set was digits. In the second arrangement the positions of the consonants and the digits were exchanged. The critical instruction was again either "letters" or "numbers" but here it indicated only the class of the required set, since the position of the consonants and digits was varied and they were all the same color. Under Cond. III the stimuli were the same as for Cond. II. However, the critical instruction was now either "outer" or "inner" so that selection of the required set was possible only on the basis of its position. Under Cond. IV, all the stimuli were consonants and two alternative arrangements were used, again with equal frequency and in random order. In one arrangement, the outer set was red and the inner set was black, while in a second arrangement the positions of the colors were reversed. The critical instruction was either "red" or "black" and selection of the required set was therefore possible only on the basis of its color. Where alternative arrangements were used, as in Cond. II, III, and IV, each arrangement was used as often when the critical instruction preceded as when it followed the neutral instruction (defined below). Cards for 32 trials under each condition were prepared. The stimuli were randomly chosen for each card except that no consonant or digit was permitted to occur more than once. The differences between the conditions are readily seen if Table 1 is examined.

The tachistoscope consisted essentially of a camera shutter and lens which projected a natural-size image of the illuminated card bearing the stimuli onto a ground glass screen. The *S* viewed the screen from the opposite side at whatever he found to be his comfortable reading distance—usually about 40 cm. The screen was masked by a cardboard rectangle except for a 4×4-cm. aperture in which the stimuli appeared. Four lines from the corners of this cardboard pointed to the center of the aperture in order to assist *S* in maintaining the correct fixation. The exposure time was .09 sec. (nominal

TABLE 1

STIMULUS MATERIALS AND CRITICAL INSTRUCTIONS

Cond.	Set	Color	Class	Critical Instructions
I	outer inner	B (black) R (red)	C (consonants) D (digits)	"letters" or "numbers"
II	*either* outer inner *or* outer inner	 B B B B	 C D D C	"letters" or "numbers"
III	same as Cond. II			"outer" or "inner"
IV	*either* outer inner *or* outer inner	 R B B R	 C C C C	"red" or "black"

shutter speed .1 sec.). The room was dimly lit and *S* recorded his report immediately after each presentation on a paper slip with a vertical line down the center, which *E* then removed. The tachistoscope was operated by a solenoid controlled by a pulse recorded on the bottom track of a length of magnetic tape. The top track of this control tape carried the two instructions (see below). The tape was fed through a two-channel tape recorder, with one output connected to the solenoid via a relay amplifier and one to a loudspeaker.

The method of preparing the tapes was as follows. Each instruction used in the experiment was recorded onto a master tape. From this tape a number of copies were made. Half of these (Type A) were recorded with the bottom track left clean and half (Type B) with a continuous square wave of 600 cps on this track. The first instruction was cut out of a Type A copy and the second instruction out of a Type B copy. These were then spliced into clean tape in such a way that the time between the beginning of the first instructions and beginning of the second instructions was 2 sec. This method ensured that the pulse which operated the tachistoscope coincided with the start of the second instruction.

On each trial a neutral instruction was given in addition to the critical instruction. The neutral instruction was either "right" or "left" and told *S* on which side of the answer slip he was to record his response. With two possible critical instructions, two possible neutral instructions, and two possible orders for the critical and neutral instructions, there were eight alternatives under each condition. A separate control tape was prepared for each of these alternatives.

All *S*s were tested individually. Alternatives in which the critical instruction came first and those in which this instruction came second were given alternately. Each *S* received eight practice trials, with each alternative represented once. This was followed in immediate succession by three sets of eight trials, with each alternative occurring once in each set. Subject to these constraints, the alternatives were given in a random order which was different for each *S*.

The 48 volunteer *S*s were graduate and undergraduate students at Birkbeck College and were unaware of the purpose of the experiment. Twelve of these *S*s were tested under each condition. Certain potential *S*s were rejected: *S*s who were unable to carry out the instructions correctly and consistently, and, *S*s who performed without error on the last four practice trials. Presumably all eight stimuli were within the perceptual span of these *S*s. The task was chosen to be not too far beyond the ability of *S*s in order to encourage the use of a central fixation point under all conditions.

RESULTS

Two scores were obtained for each *S*: (1) an *a* score, for the number of individual stimuli correctly reported (in their correct positions) under the four alternatives of each condition where the critical instruction was given first; and (2) a *b* score, for the

TABLE 2

PERCENTAGE ACCURACY OF REPORT

Instruction	Condition			
	I	II	III	IV
Critical first (*a*)	91	69	80	53
Neutral first (*b*)	75	56	81	58
(*a* − *b*)	16	13	−1	−5

numbers correctly reported under the four alternatives where the critical instruction was given second. The mean *a* scores and *b* scores are shown in Table 2 expressed as percentages. It will be seen that the difference $(a - b)$ was $+16\%$, $+13\%$, -1% and -5% under Cond. I, II, III, and IV, respectively, i.e., the accuracy of report was considerably greater when the critical instruction was given before presentation under the first two conditions but not under the second two conditions.

It was decided to analyze whether the first of these differences was significant separately from the other three, as Cond. I differed from the remaining conditions in providing more than one basis for the selection of the required stimuli. Accordingly, a t test was performed to discover whether the mean difference of $+16\%$ differed significantly from zero. The value of t was 4.1 ($df = 11$, $P < .01$). An analysis of variance was then performed to test whether the mean values of $(a - b)$ differ significantly from zero for Cond. II, III, and IV, and also whether they differ between conditions. The variability was approximately the same in the three independent groups of 12 values of $(a - b)$. The F ratio for Conditions was 9.5 (2 and 33 df, $P < .001$). This shows that the effect of the temporal positioning of the critical instruction differed significantly between the conditions. A t test was then performed to see whether the mean value of $(a - b)$ for each condition differed significantly from zero, with the SE calculated from the within-conditions variance. The values of t were 4.4, 0.5 and 1.3 for Cond. II, III, and IV, respectively. The first of these values is significant at beyond the .01 level but the other two are close to the value of unity expected on the null hypothesis. This shows that when the critical instruction was given before presentation, it increased the accuracy of report under Cond. II, as it did under Cond. I, but that no significant effect was observed under Cond. III and IV.

Discussion

The specific object of the experimental design was to eliminate the opportunity for differential effects during retention as a function of whether the critical instruction was given first or second. A potential weakness of the design is that the simultaneous presentation of the critical instruction with the stimulus field might interfere with perception more than the simultaneous presentation of the neutral instruction. If this were so, positive results—in the sense of more accurate report when the critical instruction was given first—would be attributable to the lessened interference with perception as a result of having the neutral instead of the critical instruction simultaneous with perception: they would not show that having the critical instruction before presentation makes possible a selective process during perception. Fortunately this possibility seems unlikely on the basis of the actual results obtained. For if the critical instruction produced more interference with perception than the neutral instruction, positive results should have been obtained in all four experiments unless the ad hoc assumption is made that different critical instructions interfered with perception to differing extents. In fact, however, positive results were obtained only under Cond. I and II and were not obtained under Cond. III and IV. It therefore seems safe to conclude that Cond. I and II demonstrate that a selective process can operate during perception when *S* knows which of two sets of stimuli he is to attempt to report.

The common feature of Cond. I and II was that the critical instruction told

S the class of the required stimuli. Under Cond. III it told *S* their position only, and under Cond. IV, their color only. The results thus provide evidence that a selective process can operate during perception when the class of the required stimuli is known but they fail to provide any evidence that such a selective process is possible when only the position or only the color is known. The results do however contain one rather puzzling feature. Although the same stimulus material was used under Cond. II and III, Table 2 shows that the *b* score (the score when the critical instruction was second) under Cond. II was considerably below the *b* score under Cond. III and a *t* test showed that the difference is significant at the .02 level. This might be taken to show that selection of the correct set of stimuli is inherently easier on the basis of position so that, when the critical instruction specifies the position, it is unnecessary for it to precede presentation. But if this interpretation is accepted it becomes difficult to explain why it is an advantage to have the critical instruction before presentation under Cond. I, since under this condition the critical instruction informed *S* not only of the class but also of the position of the required stimuli. An alternative interpretation of the difference between *b* scores under Cond. II and III is that they are due to a chance difference between the Cond. II and the Cond. III *S*s. Such a difference might affect the validity of comparing $(a - b)$ scores, specifically if the difference score $(a - b)$ of each *S* were correlated with his *b* score. However, examination of the relation between $(a - b)$ scores and *b* scores within each condition failed to reveal any consistent relationship between the two.

Conditions I and II demonstrate a selective process operating during perception but this process is not necessarily within perception itself. When a complex stimulus field is presented tachistoscopically, *S*'s report consists of several responses made one after another and only the first of these, if any, can be regarded as immediate in a literal sense. The efficiency of report must therefore depend partly on the efficiency with which the stimulus information is stored as it is perceived. It is possible, therefore, that the selective process concerns storage, i.e., learning, rather than perception. A previous experiment seemed to show that a selective effect on storage is indeed possible (Brown, 1954). Unless or until contrary evidence is forthcoming, it would therefore be more economical to suppose that the present results are also due to a selective effect on learning and not to an effect on perception.

Summary

The experiment investigates whether and on what bases a selective process can operate during the perception of a briefly exposed stimulus field. The field, which contained two sets of stimuli, was presented tachistoscopically for .09 sec. The *S*'s task was to report the set of stimuli specified in a "critical" instruction in a place specified in a "neutral" instruction. Under one alternative, the "critical" instruction was given 2 sec. before the stimulus field and the "neutral" instruction simultaneously with the field. Under a second alternative, the order of the two instructions was reversed. Forty-eight *S*s were tested, 12 under each of four conditions.

When the critical instruction was given in advance, *S* knew the following properties of the required set of stimuli at the time of presentation: under Cond. I, their position, color, and class; under Cond. II, their class; under Cond. III, their position; under Cond. IV, their color. Accuracy of report was significantly higher with this alternative under Cond. I and II but not under Cond. III and IV. It is concluded that a selective process which increased the accuracy of report was able to operate during perception on the basis of class but was not able to operate on the basis of position or color. Further work is needed to show whether this selective process acted in perception itself or in the concurrent learning process.

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EFFECT OF NUMBER OF DOUBLETS UPON VERBAL MAZE LEARNING

JAMES F. VOSS[1] AND J. A. ZIEGLER

Wisconsin State College at Eau Claire

Results of a previous experiment (Thompson, Voss, & Brogden, 1957) on maze patterning indicated that in a four-alternative, 16-unit verbal maze, the presentation of a doublet (two successive like responses) yielded a significant increase in errors at the second position of the doublet, regardless of the doublet locus. Since a first trial error analysis revealed that *Ss* tended not to repeat the previously correct response, the findings were considered in terms of the guessing tendencies of *Ss* and the maze pattern. Moreover, since guessing tendencies are likely maximal early in acquisition and maze pattern effects likely increase as the initial guessing habits diminish, the results suggest that the doublet effect is a differential function of two stages of acquisition, previously designated discovery and fixation (Melton, 1950).

The doublet effect is probably limited to a specific number of doublets, since use of a complete list of doublets would likely facilitate discovery of the pattern and eliminate the doublet effect. Moreover, although acquisition was not significantly influenced by the presence of a doublet (Thompson, Voss, & Brogden, 1957), facilitation would be expected with an entire list of doublets because of the probable rapid pattern discovery which would effectively shorten the sequence by one-half.

The purpose of the present study was to investigate the doublet effect and acquisition as a function of number of doublets, and to determine the relative role of discovery and fixation in these relations. Discovery was defined as the number of trials to the first correct response at a given serial position and fixation was defined as the number of trials from the first correct response to the correct response after which no further errors occurred at the particular serial position.

METHOD

One of four numbers, 10, 20, 30, and 40, was correct at each position in a 16-unit verbal maze. Each number occurred four times in one maze pattern. The control group pattern contained no doublets or split-doublets (e.g., 20–10–20) and was identical to the control group pattern employed in the study of Thompson, Voss, and Brogden (1957). For the five experimental groups, the control maze pattern was changed to provide a doublet (10–10, 20–20, 30–30, or 40–40) for Maze Units 6 and 7 in Group E_1; Units 5 and 6, 9 and 10 in Group E_2; Units 3 and 4, 7 and 8, 11 and 12, 13 and 14 in Group E_3; Units 3 and 4, 5 and 6, 7 and 8, 9 and 10, 11 and 12, 13 and 14 in Group E_4; and all pairs of maze units in Group E_5. The selection of doublet positions for Groups E_1, E_2, and E_3 was random with the limitation that no doublets occur at Maze Units 1 and 2 or 15 and 16. The pattern for each one of the experimental groups and that of the control group was permuted as in the Thompson, Voss, and Brogden (1957) study in order to provide for the representation of each number once in each of the 16 positions.

The control group and each experimental group contained 24 *Ss*. Six *Ss* were assigned to one of the four subpattern permutations of each group. Each of two *Es* handled half of the *Ss* and *E* was orthogonal to the other experimental conditions. The criterion of learning was one errorless trial. The *Ss* were volunteers from Wisconsin State College at Eau Claire and were assigned randomly

[1] Now at the College of Wooster.

to the various conditions. The instructions and other experimental conditions were analogous to those of Thompson, Voss, and Brogden (1957).

Results

The first trial data for all groups were analyzed to determine whether first trial errors increase as a function of number of doublets (Thompson, Voss, & Brogden, 1957). The Trial 1 mean errors for the Control Group was 20.0 and for Groups E_1 to E_5 were: 21.0, 21.9, 24.0, 23.6, and 25.0. An analysis of variance on the four permutations revealed no significant differences. The permutation data were pooled and a subsequent analysis of variance revealed that the number of doublets source of variation was significant (.01 level). Duncan range tests (Duncan, 1951) revealed that each group differed significantly from each other group with the exception of Groups E_3 and E_4.

Figure 1 presents the number of trials, total errors, and total time to criterion as a function of number of doublets. An analysis of variance on the four permutations for the five experimental groups and the control group revealed no significant permutation effect for any of the three measures. The permutation data were therefore pooled and subsequent analyses of variance revealed the number of doublets source of variation was significant (.01 level) for all three measures of acquisition. The E and E × Number of doublets sources of variation were not significant. Results of Duncan range tests performed on the number of doublet means are as follows:[2] trials: $\underline{E_2CE_1E_3E_4E_5}$; time: $\underline{E_2E_1E_3CE_4E_5}$; errors: $\underline{E_2E_3E_1CE_4E_5}$.

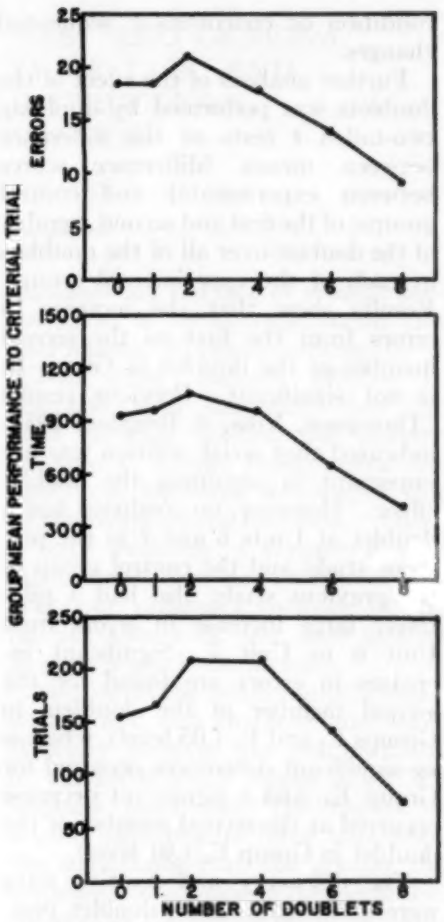

FIG. 1. Group mean performance to criterial trial as a function of number of doublets.

Analysis of variance of serial position data of the experimental groups, corrected for serial position per se by subtraction of the control group serial position means, revealed significant Serial position × Number of doublets and Serial position × Number of doublets × Permutations sources of variation. The former result indicates that serial position differences are a function of the doublet

[2] Groups underlined by a continuous line do not differ significantly from each other; groups not included in one underline differ significantly from those underlined.

condition or concomitant sequential changes.

Further analysis of the effect of the doublets was performed by applying two-tailed t tests of the difference between means (difference scores between experimental and control groups) of the first and second member of the doublet over all of the doublets in each of the experimental groups. Results show that the increase in errors from the first to the second member of the doublet in Group E_1 is not significant. Previous results (Thompson, Voss, & Brogden, 1957) indicated that serial position was not important in obtaining the doublet effect. However, no condition had a doublet at Units 6 and 7 in the previous study and the control group of the previous study also had a relatively large increase in errors from Unit 6 to Unit 7. Significant increases in errors are found for the second member of the doublets in Groups E_2 and E_3 (.05 level), whereas no significant differences occurred for Group E_4, and a significant decrease occurred at the second member of the doublet in Group E_5 (.01 level).

The discovery and fixation data were analyzed over all doublet positions for each group. The t tests indicated a significant increase in the number of discovery trials between the first and second members of the doublet for Groups E_2 and E_3 and a significant decrease in fixation trials in Groups E_1, E_3, and E_5.

Discussion

The first trial error analysis corroborates the previous findings (Thompson, Voss, & Brogden, 1957) that indicated the doublet effect is a function of guessing tendencies.

The serial position and doublet analyses indicate that the doublet effect occurs to four doublets, with a transition phase at six doublets, and a reversal of the doublet effect at eight doublets. Moreover, the discovery and fixation results, when considered with the over-all doublet analysis further supports the findings (Ernst, Hoffeld, Seidenstein, & Brogden, 1960) which attribute the doublet effect to the discovery phase of learning.

The acquisition analyses reveal that an increase from one to two or four doublets inhibited acquisition (nonsignificant), whereas eight doublets facilitated acquisition. Comparison of the acquisition results with the other findings reveals that the inhibitory factors in acquisition are associated with a significant doublet effect, primarily attributable to discovery. However, the facilitation of acquisition in Group E_5 is associated with reversal of the doublet effect and more rapid fixation.

Summary

Acquisition of a four-alternative, 16-choice-point verbal maze was studied as a function of 0, 1, 2, 4, 6, or 8 doublets. The results indicated that first trial errors increase as a function of number of doublets, that the previously found doublet effect is a function of the discovery stage of learning, and that acquisition varied as a function of number of doublets.

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THE RELATIONSHIP OF TEST AND GENERAL ANXIETY, DIFFICULTY OF TASK, AND EXPERIMENTAL INSTRUCTIONS TO PERFORMANCE

IRWIN G. SARASON AND ERNEST G. PALOLA[1]

University of Washington

Following upon the development of questionnaire techniques for assessing anxiety in *S*s, at least two lines of investigation have become clearly discernible. One line has studied the reactions of *S*s differing in anxiety scores to situations which may be considered as threatening or stressful (Child, 1954; Sarason, 1956, 1957a, 1957b). The other line has studied the relationship of anxiety scores to task characteristics, e.g., the association value and intralist similarity of material to be learned (Farber, 1955; Montague, 1953; Spence, 1958; Taylor, 1956). Although each line of investigation has produced some consistent and interesting findings, little work has been done in the direction of interrelating them. The three experiments reported in the present paper represent attempts in this direction.

Studies on the relationship between anxiety and stress have typically assumed that the performance of high-anxious *S*s would be more detrimentally affected by experimentally induced personal threat than would be true for low-anxious *S*s. Under neutral conditions no differences due to anxiety would be expected. Several experiments have provided support for these assumptions and have led to the suggestion that anxiety be conceived as a class of interfering responses which can be evoked by manipulating one set of stimuli presented to *S* in an experiment, the instructions *E* communicates to *S* (Child, 1954; Sarason 1958b). It has also been suggested that the more directly related the anxiety measure is to the experimental instructions, the more meaningful will be the relationships obtained. There is some evidence in support of this expectation (Sarason, 1958b). However, our present knowledge of the relative effects of test and general anxiety is much too limited.

Studies on the relationship between anxiety and task characteristics have typically involved the manipulation of variables which might affect *S*'s response hierarchy. The results of several experiments have supported the hypothesis that the greater the response competition in the hierarchy, the greater the advantage in performance expected of low-anxious as compared with high-anxious *S*s (Farber, 1955; Spence, Farber, & McFann, 1956; Taylor 1956).

It thus would appear that there is evidence supporting a relationship between (*a*) anxiety and stress and (*b*) anxiety and task characteristics. Despite these two sets of interesting findings a number of unresolved issues becloud the picture.

In experiments on the interaction of anxiety and experimentally induced threat there is the problem of the effect on threat arousal of the face validity for *S* of the task employed. On the other hand, studies of anxiety–

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task relationships have not systematically investigated the interaction of these variables with the motivational properties of the experimental instructions.

In each of the three experiments reported here three variables were studied: (*a*) anxiety, (*b*) task difficulty, and (*c*) differential motivating instructions. Two measures of anxiety, one general and one specific to *S*'s reactions in testing situations, were employed. Because of the use of an evaluational threat it was predicted that the latter measure would relate more systematically to performance in these experiments than would the former measure.

What will, perhaps, be of most interest in the present experiments is the possibility of the emergence of triple interactions between anxiety, instructions, and difficulty. Should triple interactions appear, the necessity of reformulating and tying more closely together the various interpretations of anxiety would seem indicated.

Experiment I

Method

Subjects. The *Ss* were 121 students in introductory psychology classes at the University of Washington. Prior to and independent of the experimental situation, *Ss* had been administered the Test Anxiety Scale (TAS) (Sarason, 1958a), the Bendig short form Manifest Anxiety Scale (MAS) (Bendig, 1956; Taylor, 1951), and the Social Desirability Scale (SDS) (Edwards, 1957).

Procedure. Each *S* performed on either an easy or difficult task. The words easy and difficult do not imply any absolute denotation but rather refer to the relative difficulty of the two tasks. The easy task was an expanded version of the digit–symbol subtest of the Wechsler-Bellevue Intelligence Scale for Adolescents and Adults, Form I. The hard task differed from this subtest only with respect to the symbols which *S* assigned to the code numbers. The nine symbols for the difficult task were variations of the letter L. Each symbol had attached to this L a different flag or hook. Thus all nine symbols differed from each other but these differences were slight and consequently increased the difficulty of making discriminations between symbols. These two forms of the digit–symbols test were administered to groups with a time limit of 3 min. After performing on the experimental tasks *Ss* were asked to rate the tasks with respect to their interest value.

Half of the *Ss* performed under "IQ" instructions, half under neutral instructions. The IQ instructions were as follows:

> The test you are about to take is part of the Wechsler-Bellevue Intelligence Scale for Adults. This test has been found to predict such things as course grades, success in later life, and to some extent the kind of personality you possess. Of course, your own intelligence will primarily determine whether you do well or poorly on this test. At a later date there will be an opportunity for each of you to compare your IQ with those of the other people in this group. You will then be able to determine how your abilities and capacities compare with other people like you.

The neutral instructions were:

> We are conducting a research project on how interesting different kinds of tests and tasks are. After completing the test I am about to give you, I'm going to ask you to rate the test in terms of how you enjoyed it. I want to make it clear that this is an experimental test and has nothing to do with any course offered at the University of Washington. We appreciate this contribution which you are making to a better understanding of the psychology of individual preferences.

Since *Ss* were not preselected in terms of TAS, MAS, and SDS, it was necessary for statistical purposes to randomly exclude certain *Ss* from the analyses of variance involving these three variables. The *N* for the TAS analysis was 104, for the MAS analysis, 108, and for the SDS analysis, 104.[2] The *Ss* were divided on these variables at the median. High-TAS *Ss* had scores of 6 and above; low-TAS *Ss*, scores of 5 and below;

[2] In each of the three experiments reported here, the various groups studied included approximately 50% male *Ss* and 50% female *Ss*.

TABLE 1

MEANS AND *SD*s OF NUMBER OF CORRECT RESPONSES FOR TEST ANXIETY GROUPS ON DIGIT–SYMBOL TEST (EXP. I)
(N = 15 for IQ Groups, N = 11 for Neutral Groups)

Test Anxiety	Difficult Form				Easy Form			
	IQ		Neutral		IQ		Neutral	
	Mean	*SD*	Mean	*SD*	Mean	*SD*	Mean	*SD*
High—	65.60	10.61	70.64	13.88	123.20	13.47	109.45	12.09
Low—	81.27	12.86	62.18	17.01	110.73	18.10	101.00	22.83

high-MAS *Ss* had scores of 4 and above; low-MAS *Ss* had scores of 3 and below. High-SDS *Ss* had scores of 33 and above; low-SDS *Ss* had scores of 32 and below. It is clear that the designations of high and low denote relative and not absolute standing on these personality dimensions.

Results

The data were analyzed by means of three 2 × 2 × 2 analyses of variances. The variables were: (*a*) high and low scores on each of the three scales used, (*b*) difficult and easy digit–symbol tasks, and (*c*) IQ and neutral instructions.

TAS. Table 1 presents the means and *SD*s for the eight experimental groups. Table 2 presents a summary of the analysis of variance. As expected, the F for difficulty of task was highly significant ($P < .001$). The groups performing under the IQ instructions performed at a significantly higher level than did the neutral *Ss* ($P < .005$). The TAS × Difficulty interaction ($P < .025$) reflects a superiority of low-TAS *Ss* to high-TAS *Ss* on the difficult digit–symbol test and a superiority of high- to low-TAS *Ss* on the easy task. Although an acceptable level of significance was not obtained for TAS × Instructions, there was a suggestion of a superiority in performance of low- to high-TAS *Ss* under the IQ condition, and the reverse was the case under the neutral condition ($.10 < P < .20$). A significant F for the triple interaction, TAS × Instructions × Difficulty ($.025 < P < .05$) was obtained. Further study of the means in Table 1 revealed that this triple interaction reflected an interaction between TAS and Instructions for the difficult digit–symbol task but not for the easy task. For the easy task, high-TAS *Ss* performed at higher levels than did the low-TAS *Ss* for both the IQ and neutral conditions. On the difficult task this superiority of high- to low-TAS *Ss* held only for the neutral condition, with the low-TAS *Ss* performing at a higher level than the high-TAS *Ss*

TABLE 2

ANALYSIS OF VARIANCE OF NUMBER OF CORRECT RESPONSES FOR EIGHT TEST ANXIETY GROUPS ON DIGIT–SYMBOL TEST (EXP. I)

Source	*df*	*F*	*P*
Test anxiety (TAS)	1	.7193	
Difficulty (D)	1	176.2386	.001
Instructions (I)	1	8.7775	.005
TAS × D	1	6.7270	.025
TAS × I	1	2.5204	
D × I	1	.5544	
TAS × I × D	1	4.9330	.05
Within groups error (MS)	96	(254.55)	
Total	103		

under the IQ condition. These results, no doubt, suggest in part the basis for failure of the TAS × Instructions effect to attain significance.

MAS. A 2 × 2 × 2 analysis of variance of the MAS data revealed only two significant effects. In addition to a significant F (189.53) for difficulty of task ($P < .001$), there was a significant F (13.13) for Instructions ($P < .001$). As was true in the TAS analysis, the groups receiving the IQ instructions performed at higher levels than the groups receiving the neutral instructions. None of the interactions obtained was significant, although there was a suggestion ($.10 < P < .20$) of an interaction between MAS scores and task difficulty, with the direction of the means similar to those obtained in the earlier TAS × Difficulty interaction.

SDS. An analysis of variance of the SDS data revealed significant Fs for Difficulty ($P < .001$) and Instructions ($P < .005$). The direction of the differences among the means was the same as in the TAS and MAS analyses. The only interaction F which approached significance was that for SDS × Difficulty × Instructions ($P < .10$).

Discussion

As predicted, TAS was more significantly related to performance than was MAS. The possibility of an interaction between the anxiety and difficulty variables was confirmed only for the TAS measure.

The results for TAS × Instructions and the TAS × Difficulty × Instructions suggest that the interaction between test anxiety and instructions held only for those *S*s who performed on the difficult task. The significant triple interaction provides a good basis for the contention that relating anxiety to either difficulty of task or experimental instructions will lead to the discovery of relationships not nearly as fruitful or meaningful as relating anxiety to both variables. On the basis of this study one might infer that both a difficult task and highly motivating conditions increase the emission of interfering anxiety responses for highly anxious *S*s as defined by TAS.

Experiment II

The main outlines of this experiment followed closely those of Exp. I with the study of the same three variables: anxiety (high and low), difficulty of task (easy and hard), and experimental instructions (IQ and neutral). However, there were task and procedural differences.

Method

Subjects. The *S*s were students in introductory psychology and introductory sociology at the University of Washington. Prior to participation in the experiment proper a large number of students had been administered the TAS and MAS. From these students those in approximately the upper and lower 20% of the TAS and MAS distributions were selected as *S*s. There were 80 *S*s (10 per experimental group) in the TAS and MAS analyses of variance. High-TAS *S*s had scores of 9 or higher; low-TAS *S*s had scores of 2 or below. High-MAS *S*s had scores of 10 or higher; low-MAS *S*s had scores of 2 or below.

Procedure. The task was the digit–symbol test administered in groups. The difficult form was identical to the one described in Exp. I. The easy form used letters of the alphabet as symbols rather than the symbols used in the comparable form of Exp. I. The *S*s performed for 5 min. on the digit–symbol test.

The IQ instructions were:

> The test you are about to participate in is part of the Wechsler Intelligence Scale for Adults. Your task is to perform as well as you possibly can. After the results have been compiled you will be given the opportunity to compare your performance on this abbreviated intelligence test to the performance of others in this group.

The neutral instructions were:

> The task you are about to perform is related to a research project conducted on individual differences here at the University of Washington. We are simply interested in the value of the particular tests you will take for further research. We wish to thank you for your cooperation in this research.

Results

Only two effects in the 2 × 2 × 2 analyses of variance involving the TAS were statistically significant. The F for Difficulty was 168.83 ($P < .001$), and the triple interaction F, TAS × Difficulty × Instruction, was 8.52 ($P < .01$). None of the other effects approached significance.

None of the Fs in the 2 × 2 × 2 analysis of variance involving the MAS approached significance.

Discussion

The significant TAS effects for Difficulty and TAS × Difficulty × Instructions are comparable to the results in Exp. I. However, there were many more significant results in Exp. I than in Exp. II. Perhaps the most important differences between the two experiments, which might explain these different results, are the instructions used. The IQ instructions of Exp. I appear to be more challenging and threatening than do the Exp. II IQ instructions. In the latter set of instructions no statement was made concerning a direct relationship between intelligence and achievement.

Although this instructional difference appears to be most striking in accounting for certain of the discrepant results of Exp. I and Exp. II there are other obvious possibilities, such as experimenter and sampling differences and differences in the easy tasks used. However, despite these factors, the fact of the consistency in the two studies with respect to the Anxiety × Difficulty × Instructions interaction has important implications. As was pointed out earlier, relating anxiety either to the instructional or to the difficulty variable would not appear to provide a sufficiently comprehensive basis for predicting results such as the triple interaction reported here.

Experiment III

The experimental design for this study was similar to those employed for Exp. I and II. Anxiety defined by TAS and MAS was related to task difficulty (easy and hard tasks) and to experimental instructions (IQ and neutral). The important difference between this experiment and the previous ones was in the nature of the task used. In the present experiment *S*s were called upon to respond to a long list of numbers by indicating to which of several rules the particular numbers adhered. A more detailed description of this task has been presented elsewhere (Palola, 1958). It was hoped that by using a different task in the present experiment it would be possible to gain information about the generality of the previously presented findings.

Method

Subjects. The same procedure for constituting high- and low-TAS and MAS groups was used in Exp. III as was used in Exp. II. The *S*s used in this experiment fell within the upper and lower 20% of the TAS and MAS distribution for a sample of 350 introductory psychology and introductory sociology students. The high and low cutoff points for the TAS and MAS distributions were the same as those used in Exp. II. The TAS and MAS analyses each had an $N = 80$ with 10 *S*s in each of the 8 experimental groups.

Procedure. The task used required *S* to indicate to which of several rules a series of numbers adhered. For the easy task, *S* was instructed to circle all numbers which were divisible by 2 and whose resulting quotient was an even number. For the difficult task seven possible rules had to be considered for each number. These rules were: (1) number

TABLE 3

MEANS AND *SD*s OF NUMBER OF CORRECT RESPONSES FOR TEST ANXIETY GROUPS ON ARITHMETIC TEST (EXP. III)

(N = 10 per group)

Test Anxiety	Difficult Form				Easy Form			
	IQ		Neutral		IQ		Neutral	
	Mean	*SD*	Mean	*SD*	Mean	*SD*	Mean	*SD*
High—	13.0	26.3	12.1	9.7	28.7	28.8	34.2	38.3
Low—	21.1	13.8	19.0	12.2	29.4	39.3	32.2	39.9

is divisible by 2 only; (2) number is divisible by 2 and 5; (3) number is divisible by 3 and 7; (4) number is divisible by 2, 3, 4; (5) number is divisible by 2 and 7; (6) more than one rule applies; (7) none of the rules apply.

The time limit for this task was 5 min. The IQ and neutral instructions were identical to those employed in Exp. II.

Results

TAS. Tables 3 and 4 present respectively the means and *SD*s and a summary of the analysis of variance of the TAS data. Table 4 reveals three significant results. In addition to the expected significant F for Difficulty, the Fs for TAS × Difficulty and TAS × Difficulty × Instructions were found to be significant ($P < .05$ and $P < .01$, respectively). Inspection of Table 3 will reveal that the TAS × Difficulty interaction was determined almost entirely by a superiority of low- to high-TAS *S*s on the difficult task. On the easy task the performances of high- and low-TAS groups were virtually identical.

The TAS × Difficulty × Instructions was largely attributable to interaction effects under the difficult condition. Under this condition low-TAS *S*s were superior to high-TAS *S*s. Under the easy condition there was a tendency for *S*s under the neutral condition to perform at a higher level than under the IQ condition.

MAS. Except for the Difficulty variable none of the Fs in the 2×2×2 MAS analysis of variance was significant.

TABLE 4

ANALYSIS OF VARIANCE OF NUMBER OF CORRECT RESPONSES FOR EIGHT TEST ANXIETY GROUPS ON ARITHMETIC TEST (EXP. III)

Source	*df*	*F*	*P*
Test anxiety (TAS)	1	3.7930	
Difficulty (D)	1	71.0690	.001
Instructions (I)	1	.7292	
TAS × D	1	5.3694	.05
TAS × I	1	.3088	
D × I	1	2.5808	
TAS × I × D	1	12.1893	.001
Within groups error (*MS*)	72	(61.85)	
Total	79		

DISCUSSION

Significant Fs involving anxiety were obtained in each of the three TAS analyses of variance. None of the Fs involving anxiety was significant in the MAS analyses. Since these three experiments involved the manipulation of an evaluational stress condition, the results seem to support the hypothesis that the more closely the anxiety scale specifically taps anxieties aroused in the experimental situation the greater the likelihood of that scale relating to behavior in the specific situation studied.

In our view the most challenging

findings in the present series of experiments were the triple interactions involving test anxiety, task difficulty, and experimental instructions. It seems likely that any comprehensive interpretation of anxiety will have to incorporate and interrelate these variables. The writers would suggest that, at least, the following factors will have to be considered in formulating theoretical and empirical directions in the study of anxiety: (*a*) the instrument used to assess anxiety and the scores obtained by *Ss*; (*b*) the nature of the task on which *S* performs (in the present experiments, the nature of the obtained triple interaction was quite different for the arithmetic task than for the digit–symbol task); (*c*) the difficulty level of the task on which *S* performs.

Summary

Three experiments were carried out involving (*a*) anxiety (test anxiety and general anxiety), (*b*) motivational and neutral instructions, and (*c*) difficulty of task. The tasks used were a digit–symbol test and an arithmetic test.

Analyzing the data by means of analyses of variance, significant Test Anxiety × Instructions × Difficulty interactions emerged in each of the three experiments. Test anxiety was related to *S*'s performance more frequently than was general anxiety (as measured by Bendig's short form of Taylor's MAS), and in general it appeared that high difficulty of task and highly motivating instructions combined to affect detrimentally the performance of high-anxious *Ss*. It was concluded that attempts at relating anxiety to either the instructional or difficulty variables alone would not be as fruitful as simultaneous analyses of the three variables.

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VISUAL PATTERN IDENTIFICATION AS A FUNCTION OF FILL AND DISTORTION [1, 2]

W. A. HILLIX

University of Missouri

The present experiment is concerned with the question, "What characteristics of a stimulus make it difficult for a human observer to identify?" There are two ways of approaching the problem. The first is to study the "absolute" characteristics of stimuli, using a paradigm in which *S* must identify the correct stimulus among others of the same general kind. In this paradigm, the stimulus to be identified is exactly the same as the one studied by *S*. Fitts, Weinstein, Rappaport, Anderson, and Leonard (1956), following Attneave (1954; 1955), have studied within this paradigm. The stimuli used were randomly constructed on various probability models. French (1953; 1954a) has also done similar work, specifically on the relationship between complexity and identifiability. Within this paradigm, the standard stimulus to be identified may either be present or absent; in the latter case, memory may be more or less important depending upon the time intervals involved and the number of stimuli studied before testing. One would expect the simplest relations to obtain where memory is minimally involved.

A slightly different situation is that in which the stimulus which should be chosen as correct differs somewhat from the standard stimulus which is supposed to be matched. One would expect this to be the more common perceptual case, since objects are seldom seen in precisely the same orientation twice, lighting varies, and so on. The paradigm in which the correct stimulus is exactly like the standard is a special case of the more general one, where the value of similarity is maximal.

Attneave (1954) gives some interesting suggestions for quantifying stimulus characteristics. Fitts et al. (1956) address themselves more specifically to the problem of "visual noise"; as more noise is added, the stimulus becomes less similar to its original form. These authors suggest that random rearrangement of the cells within a matrix is one quantifiable method of manipulating similarity. This is the method used in the present study.

French (1954b) previously worked with a problem abstractly quite similar to the present one; he varied the number of dots in a standard pattern and the number of dots added randomly to a version to be recognized. Number of dots in the original pattern and number of "noise" dots added were varied. He found that percentage of error fell as number of dots in the original pattern increased from two to nine and increased as number of noise dots increased from one to eight.

The present experiment used a dif-

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[2] Thanks are due to Robert G. Kinkade for collecting the data of this experiment.

ferent range of number of elements in the original pattern, from 10 to 50. The variations were produced by randomly moving different numbers of the original elements, from 10% to 40% of the original number of elements. The *S*'s task was to select that alternative which was most like the standard stimulus from among three stimuli, one of which had been produced by some rearrangement of the standard.

METHOD

Construction of stimuli. The stimuli were constructed in a square matrix with 10 rows and 10 columns. This gave a matrix of 100 squares, any one of which could be filled or left empty. Stimuli were constructed with five degrees of fill: 10, 20, 30, 40, and 50%. In order to do so, the rows and columns were each numbered from zero through nine so that the square to fill could be determined randomly by selecting a pair of numbers from a table of random numbers. For example, if the number was 27, Row 2, Column 7 was filled. Four such matrices were put on a page. A sample page of stimuli so constructed is shown in Fig. 1.

The stimulus on the upper left was designated the standard. The other three stimuli had the same amount of fill as the standard. The correct alternative among these three was constructed by replicating the standard and then moving the required number of randomly selected elements to new randomly selected positions that did not correspond to any of the filled squares in the standard. For example, if the stimuli are 30% filled, and we wish to accomplish a 30% distortion, nine squares are moved. The position of the correct alternative on the page was also determined randomly.

Incorrect alternatives were constructed in the same way as the standard, but were made to conform to several restrictions. The degree of correspondence between the standard and each incorrect alternative was held constant at the expected value for the given percentage of fill; four squares corresponded where the stimuli were 20% filled, nine where they were 30% filled, etc. A minor exception was the 10% fill case, where one square was made to correspond rather than the expected zero. The correspondence between the correct and incorrect alternatives was kept somewhat lower in order that the problems not be too difficult, but was again roughly proportional to the expected values. The values could not be kept arbitrarily low, since there were not enough empty squares to shift to in order to avoid both the standard and correct alternative in high fill cases. The values of correspondence chosen for the five fills were 0, 2, 6, 12, and 20 squares. Figure 1 is a case of 20% fill, 20% distortion, and close examination will show that it conforms to the above restrictions.

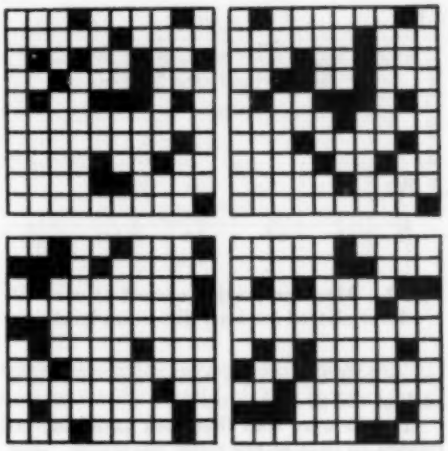

FIG. 1. Sample 20 F, 20 D problem; standard at upper left, correct alternative at upper right.

Four percentages of shift (called *distortion*) were used at each of the five levels of fill: 10, 20, 30, and 40%. Obviously distortions cannot reach a ceiling of 100%; the expected correspondence between a random alternative with 50% fill and a standard is 25 squares, which is the same as the correspondence between the standard and a "correct" alternative which is 50% distorted. Thus the maximal meaningful distortion for a 50% fill would be less than 50%.

Three different sets of four were constructed for each of the four levels of distortion and five levels of fill, giving a total of 60 problems.

Procedure. Six groups of 20 Air Force trainees at Lackland Air Force Base were used as *S*s. Each *S* was given all of the problems. A presentation of one of each of the 20 types of problems constituted a "trial"; order of presentation of the 20 problems within each trial was randomized anew for every trial and every group. Each

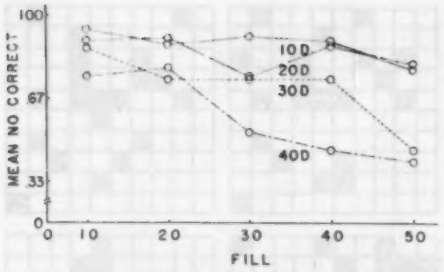

FIG. 2. Mean proportion correct at each fill level plotted for each distortion level.

group had three such trials, and thus saw each of the 60 stimuli once.

The *S*s were told that their problem was related to that of the radar navigator. The standard in the upper left corner was related to a briefing map, and the three alternatives were said to be like three parts of a radar scope display, one of which was the "target" represented on the briefing map. The *S* was to choose the correct target as quickly as possible. The *S* made his choice by writing the number of the correct alternative on his data sheet; the alternatives were numbered according to their position on the page. As soon as *S* made his choice, he wrote down the number of seconds that had elapsed since the problem had been presented; *E* counted elapsed seconds aloud, beginning 5 sec. after the problem was presented. A pilot experiment indicated that the time measure so obtained was satisfactory for the present purpose.

Stimuli were projected on a screen by means of a Baloptican projector. After instructions were completed and questions answered, *S*s were given five simple sample stimuli to make sure that the procedure was clear and fairly well practiced before beginning the actual data collection.

RESULTS

Figure 2 shows the average proportion of correct responses for the stimuli at each level of fill and distortion. There is the expected decrease in number of correct responses with increasing distortion. There is also a general tendency for correct responses to decrease with increasing fill, although this seems to be largely due to the marked decrease in correct responses at the highest distortion value for the 30%, 40%, and 50% fill cases. This large decrease also leads to a Fill × Distortion interaction. An analysis of variance showed that these three effects were significant at beyond the .01 level.

The results from the time scores agreed remarkably well with those from the number of correct responses. Comparison of Fig. 2 and 3 shows this close agreement. The correlations between the time and correct responses ranks in the F × D tables is .92. For time scores, Fill, Distortion, and the Fill × Distortion interaction were again significant at beyond the .01 level.

The effects of Trials, as trials were defined in this experiment, were significant ($P < .05$) but relatively slight. The effect on time scores was more stable than was the effect on number of correct responses. For time scores, trials remain significant when tested over their largest interaction with other variables, but this is not the case with the number of correct responses.

The Fill × Distortion interaction is perhaps the most interesting result. Attention was given to finding an index which would enable the difficulties of each of the classes of problems to be "predicted." It turned out that an "index of relative simi-

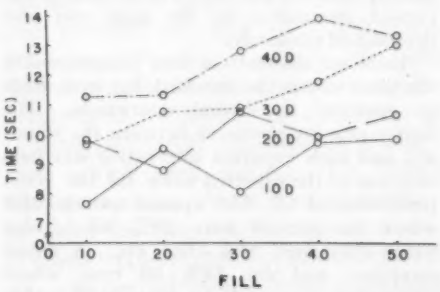

FIG. 3. Mean time per response at each fill level plotted for each distortion level.

larity" could account for a large amount of the variance within the Fill × Distortion table, whether for time or for correct response scores. The relative similarity was defined as the number of filled squares that corresponded between the standard and the correct alternative, minus the number of filled squares that corresponded between the standard and the incorrect alternatives, divided by the number of squares filled in each of the stimuli. In the 10% fill, 10% distortion, case the similarity is highest. Its value here is $\frac{9-1}{10} = .8$. Nine is the number of squares that are filled in the same positions on both the standard and the correct alternatives, one is the number filled in the same positions on both the standard and the incorrect alternatives, and 10 is the number of squares filled on each of the four matrices. Table 1 shows the values of the index for each cell of the Fill × Distortion table. All correct response scores for a given value of the index were totaled, and the mean number of correct responses obtained for each value of the index. A regression line was fitted to the resulting plot; the equation for the line of best fit was $C' = 138.85 + 280.63\ I$, where C' = the predicted number correct, and I the value of the index. The proportion of the variance accounted for by their correlation with the index was quite high, as indicated by the value of $r^2 = .88$.

The time scores were treated in the same way. The regression line was $T' = 5172.34 - 2912.76\ I$, where T' is the predicted mean time to respond. Again r^2 is quite high (.92). Although r^2 was high for both measures, it was obvious by inspection that an appropriate sigmoid curve would have fitted the points for number of correct responses even better than the straight line actually used. This is not true for the time scores.

TABLE 1

"RELATIVE SIMILARITY" FOR EACH VALUE OF FILL AND DISTORTION

Distortion	Fill				
	10%	20%	30%	40%	50%
10%	.8	.7	.6	.5	.4
20%	.7	.6	.5	.4	.3
30%	.6	.5	.4	.3	.2
40%	.5	.4	.3	.2	.1

In spite of the apparent success of the index, it was noted[3] that there were systematic differences in the time scores, due to distortion level, when the separate distortions were plotted against the values of the index; thus the index did not take sufficient account of distortion as it affected time. There were no residual effects of distortion on the correct response scores.

A revision was accordingly made in the index as applied to time scores; the revised index is simply $I + (.4 - D)$, where I is the original index and D the level of distortion. The new index incorporates distortion twice, once in the calculation of the original index and once in modifying it. When the time values were plotted against the revised index separately for each distortion level, there were no longer any systematic differences in the curves. It now seemed justifiable to combine the several levels of distortion according to their index values. The equation for the regression line fitted to the 11 values of the new index was $T' = 5150.79 - 2131.44\ I_1$, where I_1 is the new index. The value of r^2 increased to

[3] I am indebted to F. Attneave for a critical reading of this manuscript, and for pointing out these effects.

.94, despite the larger number of values and corresponding decrease in their reliability for the new index.

These regression lines are of course specific to the situation and probably hold only for this set of conditions. Some of the limiting factors are the fact that it is a three-alternative situation, there is a 20-sec. time limit for responding, and the stimuli were constructed according to the specified procedure. Nevertheless, the curves are at least a start toward the specification of difficulty of identifying stimuli, and they incorporate some of the factors that must be taken into account if stimulus difficulty is to be quantified.

Discussion

The present study is at least a clear demonstration that any analysis and quantification of perceptual difficulty must consider parameters based on the relationship between test alternatives as well as those based on the stimulus that is initially studied. It must also consider the various relationships between the stimulus studied and the one designated correct. There is nothing wrong in relating the absolute characteristics of the stimulus to the difficulty in identifying it among a group of similar alternatives, but it seems that a complete picture of perceptual difficulty must consider what happens when the standard stimulus is distorted. For example, in the present study it matters little whether the grid is 10% or 50% filled if distortion is minimal, but it matters a great deal if distortion is maximal. Exclusive study of the no-distortion case might yield results which tend to mislead.

Another facet of the problem is the importance of the kind of operation used in producing distortion. French (1954b) added irrelevant elements and changed the orientation of the stimulus; other possible distortions might shift the outlines of solid figures, subtract elements, and the like. Different functions will no doubt be required to describe the difficulty following from each of the different operations. And each of these functions would probably be modified according to the importance of memory in the task.

It is possible that the task of describing perceptual difficulty might be reduced by referring the different classes of operations to a common mathematical basis, like that afforded by information theory. This is simple enough to do for the stimulus considered in isolation, but not so simple for the several kinds of distortion. For figures constructed on a model like the present one, the number of bits equals $\log_2 \frac{n!}{r!n-r!}$, where n is the total number of positions in the matrix, r is the number of filled squares, and $n - r$ is the number of empty squares. The function reaches its maximum at $r = n - r$, and is symmetrical about that point. For the present stimuli, the numbers of bits for 10% through 50% fill were approximately 44, 69, 85, 94, and 97. The use of the information model may or may not make it possible to simplify stimulus-response relationships for different types of stimuli.

Summary

Stimuli were constructed in a 10×10 grid by a random sampling procedure. The number of elements filled in was varied in steps from 10% through 50%, and the number of elements rearranged from the standard stimulus to make the correct alternative was varied from 10% through 40%. The combination of fill and distortion resulted in 20 stimulus classes. The *Ss*' task was to choose the stimulus that most closely resembled the standard from the three alternatives presented. Each of 120 Lackland Air Force Base trainees had all 20 stimulus conditions. Fill, distortion, and their interaction all had significant effects on time to respond and on number of correct responses. An "index of relative similarity" was developed to "predict" problem difficulty, and showed a close relationship to both number of correct responses and time to respond. Some further suggestions were made for the quantification of perceptual difficulty.

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EFFECT OF AMOUNT OF PRECONDITIONING TRAINING UPON THE MAGNITUDE OF SENSORY PRECONDITIONING [1]

DONALD R. HOFFELD, [2] STEPHEN B. KENDALL, RICHARD F. THOMPSON, [3] AND W. J. BROGDEN

University of Wisconsin

The phenomenon of sensory preconditioning was presented by Brogden (1939) with the implicit assumption that its quantitative variation and the independent variables to which it is functionally related are similar to those of conditioning. Brogden (1950) reported briefly about two experiments on sensory preconditioning in which variation in the number of preconditioning training trials appeared to have no differential effect upon the magnitude of the phenomenon. Because of the fundamental relation of amount of training to amount of conditioning, it was assumed that there were errors of some kind in the experiments, rather than that sensory preconditioning differs in respect to this relationship from standard conditioning. Hoffeld, Thompson, and Brogden (1958) studied the stimuli time relations during preconditioning training for conditions of 0, .5, 1, 2, and 4 sec. precedence of tone over light and found maximum sensory preconditioning to tone for 4 sec. precedence. Since these results are not compatible with the results on time relations during standard conditioning, these authors suggest that sensory preconditioning may be markedly different from conditioning. It is possible that the variables known to affect conditioning may have an effect upon sensory preconditioning also, but that the nature of the effects will be different. Sensory preconditioning may be a phenomenon separate from standard conditioning, with a set of different relationships. Seidel (1959) in his recent review of studies of sensory preconditioning has also suggested this possibility.

The present study was planned with the assumption that sensory preconditioning is a phenomenon different from standard conditioning. Number of trials of preconditioning training was selected as the independent variable because of the fundamental character of the positive relation of amount of practice to amount of conditioning in learning fact and theory. A difference in this relationship for sensory preconditioning will be of primary importance in distinguishing it from standard conditioning. Three alternative hypotheses were considered: (*a*) that amount of sensory preconditioning will be a direct positive function of the number of trials of preconditioning training; (*b*) that amount of sensory preconditioning will be independent of number of trials of preconditioning training, once a sufficient number of trials has been given to produce the phenomenon; and (*c*) that as the number

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[2] Now on active duty, United States Air Force, assigned to Human Engineering Laboratory, Rome Air Development Center.

[3] Now in Department of Medical Psychology, University of Oregon School of Medicine.

of preconditioning trials increases, sensory preconditioning will appear first at a minimum magnitude, then increase to a maximum, and thereafter decline.

The initial experiment to test these hypotheses included values of 0, 10, 20, 40, 80, 200, and 400 preconditioning training trials.[4] The results show a significant amount of sensory preconditioning for all conditions greater than zero trials, but no significant differences in magnitude, although the amount of sensory preconditioning for 200 trials of preconditioning training was numerically greater than for any other condition. The experiment was expanded in two ways in order to provide differential support for either the second or third of the hypotheses presented above. One was the addition of the following values of preconditioning training trials: 1, 2, 4, 8, and 800. The other was an increase of n per group from 4 to 6. Thus, the second phase of the experiment involved the testing of 6 animals each for the 1, 2, 4, 8, and 800 trial groups and 2 animals each for the 0, 10, 20, 40, 80, 200, and 400 trial groups.[5] Further presentation will be as if there had been a single coordinated experiment from the beginning.

Procedure

All experimentation was conducted in a sound-insulated, light-shielded room with the rotating cage of Brogden and Culler (1936) as the conditioning apparatus and under the general conditions described by Hoffeld, Thompson, and Brogden (1958). The conditions for the tone and light during preconditioning were the same as in the earlier study, except that the tone preceded the light by 4 sec., but overlapped for the 2 sec. duration of the light. These time relations were selected for preconditioning training because of the maximum amount of sensory preconditioning obtained for these conditions by Hoffeld, Thompson, and Brogden (1958). During the other phases of the procedure, avoidance conditioning to light, critical test with tone, and extinction to light, the duration of the light and the tone was 2 sec., and except for number of trials of preconditioning training, the procedure replicates that of Hoffeld, Thompson, and Brogden (1958).

The 72 cats of the experiment were assigned at random in two stages (see introduction) so that N for each of the 12 groups was 6. Three *E*s tested *S*s so that each *S* was tested by a single *E* for preconditioning training or for avoidance conditioning, critical test to tone, and extinction to light. In the majority of cases, a single *E* conducted both the preconditioning training and the subsequent phases of the experiment on the same *S*. However, *E* was not orthogonal in the experimental design. The daily experimental session involved 20 trials of the appropriate condition, except in the case of *S*s assigned to groups for 0, 1, 2, 4, 8, and 10 trials of preconditioning training. The preconditioning training of *S*s assigned to groups for 20, 40, 80, 200, 400, and 800 trials involved 20 trials per test period for 1, 2, 4, 10, 20, and 40 test periods, respectively. Following the preconditioning training, all *S*s received: (*a*) instrumental avoidance training with 2 sec. light CS and .1 sec. shock UCS until the conditioning criterion of 90% CR (18 or more cage-turning shock-avoiding CRs for the 20 trials) was reached; (*b*) tests for sensory preconditioning by presenting a 2 sec. tone CS until frequency of CR in a given test period was 10% or less; (*c*) extinction of the CR to the light CS until the criterion of 10% or less CR in a given test period was reached.

The *S*s were relatively quiet during preconditioning training. Since no cage-turning response occurred to any presentation of the preconditioning stimuli, this requirement of the sensory preconditioning paradigm (Brogden, 1939) was met. During instrumental avoidance training a CR was defined as a cage-turing response that occurred before the termination of the CS. The occurrence of a CR provided for avoidance of the electric shock UCS. This same criterion of response was maintained for the critical tests to tone and the extinction to light except that no shock was involved. The intertrial interval for all procedures varied between 15 and 30 sec.

[4] Consideration was given to the inclusion of control groups involving presentation of trials of tone alone during the pretraining period equal in number to the frequency of preconditioning training for the experimental groups. The failure in a number of studies of sensory preconditioning (Brogden, 1949; Chernikoff & Brogden, 1949; Coppock, 1958; Seidel, 1958; Silver & Meyer, 1954) to find any effect for noncontiguous presentation of the preconditioning stimuli makes the heavy investment of animals and time unnecessary.

[5] Hoffeld collaborated in the first and Kendall in the second phase of the experiment.

TABLE 1

MEASURES OF SENSORY PRECONDITIONING AND ACQUISITION

S	Group and Number of Preconditioning Trials											
	C 0	E_1 1	E_2 2	E_3 4	E_4 8	E_5 10	E_6 20	E_7 40	E_8 80	E_9 200	E_{10} 400	E_{11} 800
Frequency of Responses to Posttest Trials of Tone												
1	0	0	3	55	2	14	8	11	2	15	2	5
2	0	1	0	4	8	5	2	2	11	10	3	0
3	0	1	23	9	6	1	2	4	2	6	1	0
4	0	1	0	22	2	1	4	8	2	7	2	4
5	0	1	4	5	4	1	1	6	2	18	8	2
6	0	2	2	50	9	3	2	2	6	7	2	1
Mean	0.00	1.00	5.33	24.17	5.02	4.17	3.17	5.50	4.17	10.50	3.00	2.00
Test Periods to the Criterion of Conditioning												
Mean	7.83	8.50	6.83	11.67	5.50	5.83	7.33	6.17	6.33	4.63	6.50	9.50
Frequency of Responses to Extinction Trials of Light												
Mean	11.00	21.50	6.17	14.00	6.00	7.67	7.00	4.50	7.00	5.83	9.17	11.83

RESULTS

Examination of the data for acquisition, cross-modal stimulus generalization, and extinction (see Table 1) suggested the possibility of relationship between acquisition and each of the latter. Coefficients of correlation were computed for number of test periods to the conditioning criterion and both frequency of response and number of test periods for the tests to tone and extinction to light. No correlation coefficient is significantly different from zero. Analysis of variance of the acquisition data (see Table 1) produced an F ratio significant at the 5% level, but not at the 1% level. In view of the fact that the value of χ^2 is nearly equal to the value at which the hypothesis of homogeneity of variance must be rejected, the conclusion that there are significant differences in acquisition is tenuous. Since this result does not differentiate the control and experimental groups from each other, there is no evidence that acquisition influences the occurrences of sensory preconditioning as such. Differential magnitude of sensory preconditioning may be affected by acquisition, since Group E_3 shows the slowest acquisition and the maximum amount of sensory preconditioning. The results of Tukey's test for multiple comparisons (Ryan, 1959) of the acquisition data shows the mean for Group E_3 (largest mean) to be significantly different at the 5% level from the mean for Group E_9 (smallest mean). There are no other significant differences among these means.

Analysis of variance of the extinction data produced an F ratio whose value was considerably less than the value of F at the 5% level of significance. The consistent failure of extinction following the critical test for sensory preconditioning (Brogden,

1947; Chernikoff & Brogden, 1949; Hoffeld, Thompson, & Brogden, 1958) to demonstrate any secondary extinction effect between the experimental and control conditions suggests the conclusion that there is no such relation and that this procedure is completely ineffective for the measurement of sensory preconditioning.

A t test of the mean difference in frequency of response to the tone (cross-modal stimulus generalization) for the control group versus the experimental groups ($P = .0003$) established the reliability of sensory preconditioning for the experimental groups. An orthogonal polynomial analysis of variance (Grant, 1956) was completed on the measures of sensory preconditioning for all of the experimental groups and the results of this analysis are given in Table 2.[6]

[6] Since the orthogonal polynomial analysis requires equal intervals of the independent variable, a choice must be made between the inclusion of data for Groups E_4 and E_5. A toss of the coin eliminated Group E_5 from the data presented in Table 2 and the orthogonal polynomial equation presented in Fig. 1. An analysis that used the data for Group E_5 in the place of Group E_4 gave very similar results to those presented.

TABLE 2

ANALYSIS OF VARIANCE OF RESPONSES TO TONE BY EXPERIMENTAL GROUPS

Source	*df*	*MS*	*F*
Between groups	9	274.30	4.03*
Linear	1	105.94	1.56
Quadratic	1	196.00	2.88
Cubic	1	217.70	3.20
Quartic	1	599.72	8.82*
Quintic	1	6.03	0.09
Sextic	1	571.21	8.40*
Residual	3	257.37	3.78
Within groups	50	68.03	

* $P = .01$.

Since the assumption of homogeneity of variance could not be accepted, the 1% level was used for the statistical tests of these data. The F ratio of the between and within variances is statistically significant, and

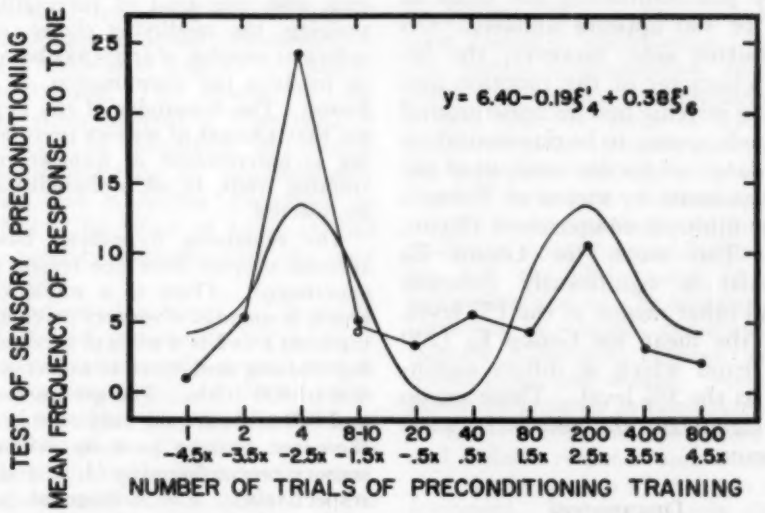

FIG. 1. Relation between magnitude of sensory preconditioning and number of trials of preconditioning training. The smooth curve is a plot of the orthogonal polynomial equation. The means of the data included in the orthogonal polynomial analysis of variance are represented by the closed circles. The open circle is the mean for Group E_5. The straight line curve connecting the means is drawn to the mean of the means for Groups E_4 and E_5.

demonstrates significant differences between the experimental group means. The significance of the quartic and sextic sources of variation demonstrates that there are significant quartic and sextic components in the relation of magnitude of sensory preconditioning to number of preconditioning training trials. Figure 1 presents the best fitting orthogonal polynomial equation and the empirical data points. This equation is not an adequate representation of the relation for several reasons. It provides for a significant amount of sensory preconditioning (6.4 responses) at zero trials of preconditioning training and even greater magnitudes for negative trials of preconditioning training. It provides for no sensory preconditioning in the approximate range of 15 to 60 trials of preconditioning training. All of this is contrary to the empirically obtained results and must be rejected. In addition, the increase in amount of sensory preconditioning for trials in excess of 800 appears unlikely. On the positive side, however, the bimodal character of the function and trends of increase and decrease around each mode appear to be representative of the data. A further analysis of the data was made by means of Tukey's test for multiple comparisons (Ryan, 1959). The mean for Group E_3 (4 trials) is significantly different from all other means at the 1% level, except the mean for Group E_9 (200 trials) from which it differs significantly at the 5% level. There are no other significant differences between the means.

Discussion

Of the three alternative hypotheses which the experiment was designed to test, the one relating amount of sensory preconditioning positively to number of trials of preconditioning training is not supported by the results and therefore is rejected. The results do not, however, provide clear and distinct support for either of the other hypotheses: that amount of sensory preconditioning is independent of number of preconditioning trials, once a sufficient number of trials has been given to produce the phenomenon, and that as the number of preconditioning trials is increased, the amount of sensory preconditioning will appear first at a minimum magnitude, then increase to a maximum, and thereafter decline. The results of the orthogonal polynomial analysis of variance and of Tukey's test for multiple comparisons are in opposition to the first of these hypotheses. There is the possibility, however, that the large amount of sensory preconditioning for Group E_3 (4 trials) is due to a slower acquisition of the CR. The results of the analysis of the acquisition data are indefinite and the failure to find any significant correlation between speed of acquisition and amount of sensory preconditioning gives no support to this view. Since sensory preconditioning occurs with one trial of preconditioning training, the modifying clause, once a sufficient number of trials has been given to produce the phenomenon, is superfluous. The remainder of the hypothesis, that amount of sensory preconditioning is independent of number of pretraining trials, in all probability should be rejected.

The remaining hypothesis has substantial support from the results of the experiment. There is a numerical increase in amount of sensory preconditioning from 1 to 2 to 4 trials of preconditioning training and there is a decline from 400 to 800 trials. The groups for 1, 2, and 800 trials are the only ones in which there are *S*s who gave no evidence of sensory preconditioning (1, 2, and 2 *S*s, respectively). The orthogonal polynomial analysis supports these trends. It provides, however, for no sensory preconditioning within the approximate range of 15 to 60 trials of preconditioning training. This is contrary to fact and

cannot be accepted. The orthogonal polynomial analysis also provides two maxima, one at 4 trials and the other at 200 trials, whereas the results of Tukey's test provide for a maximum only at 4 trials.

If we consider that during preconditioning training the tone is a CS and the light a UCS (UCR implicit and unknown), the development of the CR (implicit and unknown) must be a function at least of the temporal relations of the light and tone (Hoffeld, Thompson, & Brogden, 1958) and of the frequency of presentation of these stimuli. The CR occurs after 1 trial and its strength increases up to 4 trials and thereafter declines, but not below the 1 trial level up to and including 800 trials. The decline may be a function not only of the number of trials but also of their distribution, since trials in excess of 20 were given by test periods of 20 trials. A decremental function due to repetition should show some recovery or less decline as a function of distribution. The massing of trials within a single test period with a standard intertrial interval should provide the most precise measurement of any decline in the magnitude of sensory preconditioning as a function of member of trials of preconditioning. The results of the present study support a hypothesis of an increase in magnitude of sensory preconditioning up to approximately 4 trials and a decline thereafter to 20 trials. The effect of trials beyond 20 is possibly contaminated by their distribution.

Any information about a CR established by the preconditioning trials of tone and light depends upon inference made from the results of test of cross-modal stimulus generalization. Since the phenomenon of sensory preconditioning is measured as a transfer effect, its measurement may be affected by the method of measurement. Thus any variable that affects stimulus generalization would affect the measurement of sensory preconditioning (Thompson, 1959). Use of the appropriate control, however, should demonstrate any effect of variables of stimulus generalization unless there are interactions of these variables with those affecting sensory preconditioning.

Measurement of cross-modal stimulus generalization by the extinction procedure involves the assumption that resistance to extinction is a direct measure of the strength of conditioning. Although the bulk of evidence supports this assumption, it is clear that extinction is not a highly reliable measure of the strength of a CR (Brogden, 1951). The unreliability of extinction measures undoubtedly contributes to the unreliability of the relation of number of preconditioning trials to magnitude of sensory preconditioning. In spite of this unreliability, however, the relatively large measure of sensory preconditioning for the 4-trial group is impressive. The mean of 24.17 responses to the tone represents a strength of CR between the tone and the light substantially greater than that obtained by 4 trials of standard conditioning procedure.

The results of the present study support the view that sensory preconditioning is a phenomenon of learning different from standard conditioning. Whether the further interpretation should be made that sensory preconditioning is a unique type or class of learning is another matter. Sensory preconditioning may occur concomitantly and be a part of standard conditioning. The procedures for standard conditioning are similar to those of preconditioning training and the phenomenon of sensory preconditioning may be necessary to the formation of standard conditioning. A primary difference between standard conditioning and sensory preconditioning is the presence in procedures for the former of a stimulus that evokes a clear and definite response and whose function can be spoken of in terms of reinforcement. Perhaps the only difference between standard conditioning and sensory preconditioning is in terms of performance and that the primary role of reinforcement is in terms of performance.

SUMMARY

The experiment was conducted on 72 cats who in groups of 6 were given 0, 1, 2, 4, 8, 10, 20, 40, 80, 200, 400, and 800 preconditioning training trials of a 6-sec. tone and 2-sec. light. After avoidance conditioning was established to the light, tests of cross-modal stimulus generalization to the tone were obtained as measures of sensory preconditioning. There was no response to the tone by the animals of the control group (0 trials) whereas all of the experimental groups showed significant amounts of sensory preconditioning. The magnitude of sensory preconditioning increases progressively through 1 and 2 preconditioning trials to a maximum at 4 and then declines to an approximately uniform level for 8, 10, 20, 40, and 80 trials, increases at 200 trials, and then declines progressively at 400 and 800 trials. An orthogonal polynomial analysis of variance shows significant differences between means and a trend with quartic and sextic components. Tukey's test for multiple comparisons indicates only that the mean for 4 trials is significantly greater than any of the other means. These results appear to establish a function of increase of sensory preconditioning as trials increase from 1 to approximately 4, and then a decrease. The form of the function beyond the level of the decrease is in question.

Since the hypothesis that amount of sensory preconditioning increases as a function of number of preconditioning trials must be rejected, the results of the present experiment provide additional evidence that sensory preconditioning is a different kind of phenomenon from standard conditioning. Some of the theoretical considerations of this viewpoint are discussed.

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SUPPLEMENTARY REPORT: THE RELATIONSHIP OF INDUCED MUSCULAR TENSION TO MANIFEST ANXIETY IN LEARNING[1]

O. IVAR LOVAAS

University of Washington

The present study investigated the possibility of reproducing the characteristic features of the performance of *Ss* scoring high on the A scale as determined by Spence, Taylor, and Ketchel (1956), by inducing muscular tension experimentally in randomly selected *Ss*. The learning task employed had been shown by Spence, Taylor, and Ketchel (1956) to discriminate between *Ss* who score high and low on the A scale.

Method. The *Ss* were 12 randomly selected, experimentally naive, male graduate students in psychology. A "tension" group (6 *Ss*) learned a set of paired adjectives while pressing a Smedley hand dynamometer during the actual trials; a "no tension" group (6 *Ss*) learned the set without any induced muscular tension.

A presentation device showed each stimulus word of a pair for 1.7 sec., then showed the response word for 2.3 sec., after which the stimulus word of the next pair immediately appeared. Inadequacies in the apparatus allowed an *SD* of about .1 sec. in the various exposure times. Intervals between trials were 10 sec.

A dynamometer was located on each side of the exposure window, about 25 in. apart and about 20 in. from *S*. The handles were padded. Tension was induced only in the preferred hand. The dynamometer pointer closed a circuit to light a bulb located 2 in. above one corner of the exposure window, whenever *S*'s pressure was ±3 lb. of the required pressure. During the learning trials each "tension" *S* squeezed this handle at half the maximal pressure exerted during the 30th sec. of a grip-pressure pretest. The tension signal light was kept on by *S* during each trial. The *Ss* in the "no tension" group merely gripped the handle, and contact on the dynamometer allowed a pressure of only 3 lb. to turn the light off.

In order to avoid incentive motivation differences between the groups all *Ss* were told that they would work for a predetermined number of trials, that if they got all correct one time they should attempt to get all correct again, and that they should do their best on each trial. A practice session of six trials on 10 paired nouns, with use of the dynamometers begun on Trial 3, was followed after 1 min. by a reading by *S* (aloud) of a nonpaired list of the adjectives to be learned. Errors of pronunciation were corrected. The set of adjectives was then learned by the anticipation method until *S* achieved two errorless trials or for a maximum of 33 trials. Pairs were shuffled after each presentation.

The set of adjectives used is presented by Spence, Taylor, and Ketchel (1956, Table 1, p. 307) along with the theoretical rationale and predictions for the performance of high- and low-drive *Ss* on these pairs. Four out of the 10 pairs have stimulus and response words that are highly associated (high-associated pairs) and six pairs are such that the stimulus word tends to elicit more than one response word (competing pairs). Performance of high-drive *Ss* should be inferior to low-drive *Ss* on the competing pairs. On the four highly associated pairs, high-drive *Ss* should show superior performance initially. With increased training, they should increasingly give response words *other* than those originally paired with the stimulus words. The initial superiority of the high-drive *Ss* should disappear when these pairs become characterized by much response competition.

Results. Figure 1 shows the learning curves for the "tension" and "no tension" groups on the four highly associated pairs and on the six competing pairs. The insert in Fig. 1 is a rough reproduction of the curves from the study by Spence, Taylor, and Ketchel (1956). They used the same set of paired adjectives but employed *Ss* scoring high and low on the Taylor Manifest Anxiety Scale. As can be observed, results from the two studies are strikingly similar. The results are consistent with the hypothesis that the performance of *Ss* who score high on the A scale can be approximated by *Ss* assumed to score lower on the A scale working under induced muscular tension.

Further support for the drive properties of induced muscular tension is to be found in the

[1] This article is taken from a thesis submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, University of Washington, 1958. The author is indebted to Moncrieff H. Smith, Jr., under whose direction the thesis was prepared.

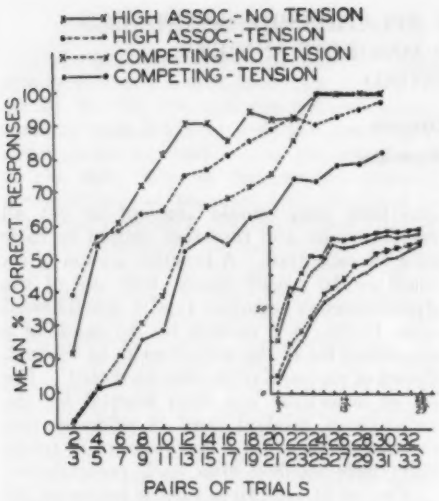

FIG. 1. Paired-associate learning as a function of induced muscular tension ("tension") and no induced tension ("no tension"). The insert shows the results of Spence, Taylor, and Ketchel (1956) employing the same paired associates, but with high-anxious (replacing "tension") and low-anxious (replacing "no tension") *Ss*.

significant experimental Condition × Trials (2 through 10) interaction on the highly associated pairs ($F = 3.93$; $P < .01$). The interaction analysis was carried only through Trial 10 in order to preserve homogeneity of variances since many *Ss* reached mastery beyond the trial and because previous studies (Spence, Taylor, & Ketchel, 1956; Spence, Farber, & McFann, 1956) had demonstrated that the reversal of superiority between high- and low-drive groups took place by Trial 5. On the Spence, Farber, and McFann assumption (1956, p. 299) that the highly associated pairs become characterized by an increase in response competition with increase in trials, the significant experimental Condition × Trials interaction supports induced muscular tension as a *D* variable.

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SUPPLEMENTARY REPORT: RETENTION AND TRANSFER OF RESPONSES TO STIMULUS CLASSES

KENNETH E. LLOYD[1]

University of Virginia

Transfer to new instances of a class is less for *Ss* who see only one instance of a class during original learning (L-I) than for *Ss* who see more than one instance (Lloyd, 1959). The former *Ss* (Specific Group) can learn a paired-associate task without recourse to a mediating response (the class name), and are not set to respond to a new instance at the transfer task (L-II). Once the mediating response is appropriate, however (i.e., in Class Groups when more than one instance is used at L-I), then transfer should be independent of the number of instances seen in L-I.

This study repeats the design of the former Exp. I with four changes: at L-I three groups (one specific and two class groups) saw one, two, or six instances; after the one-week recall the groups transferred to lists containing six, two, and six new instances, respectively; the 18 male *Ss* in each group were volunteers from psychology classes at the University of Virginia; no latency measures were taken. At L-II the class groups should not differ, but should exceed the specific group.

Both the means and *F* ratios in Table 1 agree with those of the prior study. Tests of individual *df*'s indicate that at L-I the class groups required more trials than the specific group ($F = 14.05$; $P < .01$). Neither recall nor loss scores differed significantly. At L-II the class groups did not differ ($F < 1.00$), but they made more correct responses than the specific group ($F = 44.87$; $P < .01$). Two conclusions are appropriate: the recall results of the prior study are not limited to the number of instances that were used, and the variable contributing to the transfer results seems to be whether or not the class name is ever used as a mediating response.

[1] Now at Washington State College.

TABLE 1

TRIALS TO CRITERION (L-I), RECALL, LOSS SCORES, AND CORRECT RESPONSES (L-II)

Group	L-I Trials		Recall		Loss Scores		L-II, Trial 1	
	Mean	*SD*	Mean	*SD*	Mean	σ_M	Mean	*SD*
1–6	6.11	1.59	20.50	3.49	2.99	.83	12.78*	4.38
2–2	8.56	2.93	19.11	3.63	3.76	.86	19.33	2.79
6–6	8.83	2.24	20.11	2.49	3.35	.64	19.22	2.25
F ratio (df = 2,51)	7.09*		<1.00		<1.00		22.46*	

* $P < .01$.

At L-II in Exp. I of the prior study the performance of Group ES improved rapidly over the first three subtrials. These *S*s could have been employing the class name, or could have been simply learning a second list. Group 1–6 should begin to employ the class name at L-II. Inspection of the first six subtrial means at L-II for these two groups reveals that Group 1–6 makes fewer correct responses at all points except the first subtrial. Since responding to classes of stimuli is more difficult, these data suggest that at L-II Group ES did not employ a class name, while Group 1–6 was learning to do so.

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SUPPLEMENTARY REPORT: TWO-CHOICE BEHAVIOR OF MONKEYS[1]

WILLIAM A. WILSON, JR.

University of Colorado

Monkeys trained in a .75–.25 noncontingent probability learning situation quickly reached an asymptote of approximately 100% choice of the .75 side, when correction was not permitted (Wilson & Rollin, 1959). The data suggested that *S*s would have reached the same asymptote, albeit more slowly, when immediate correction was permitted, but the experimental sophistication and sequence of training of *S*s did not permit a definite conclusion on this point. This paper reports on the behavior of naive *S*s under the same correction procedure, as well as on *S*s subjected to a "guidance" procedure in a contingent situation (Bitterman, Wodinsky, & Candland, 1958).

Method. Eight immature naive cynomolgus monkeys were used. A two-choice apparatus was used, modified slightly from one previously described. Two black plastic boxes, which served as covers for shallow food wells, were hinged at the back and weighted so that if the front of a box were slightly raised the box would open completely. A clip could be attached to connect the boxes so that opening either would cause both to open. Two "half-clips" could be attached to present a similar appearance, although leaving the boxes independent.

The *S*s were presented with a .75–.25 random situation, as described in the previous report; for half the *S*s in each group the left was the more often baited side. For the Correction Group (four *S*s), the clip was used, and, as in Part 3 of the earlier study, after *S* opened an unbaited box, he was permitted to retrieve the peanut from the other food well. For the Guidance Group, the half-clips were used. After *S* opened an unbaited box, the screen was closed, and then reopened, allowing *S* now to open the only closed box, the baited one.

Results. On the first day of testing, the two groups had similar wide ranges (Correction: 21.9%–100%; Guidance: 28.1%–84.4%) and means of approximately 60% choice of

[1] This research was done at the Institute of Living and was supported in part by the Research and Development Division, Office of the Surgeon General, Department of the Army, under Contract No. DA-49-007-MD-763. Most of the data were gathered by Ann Warren.

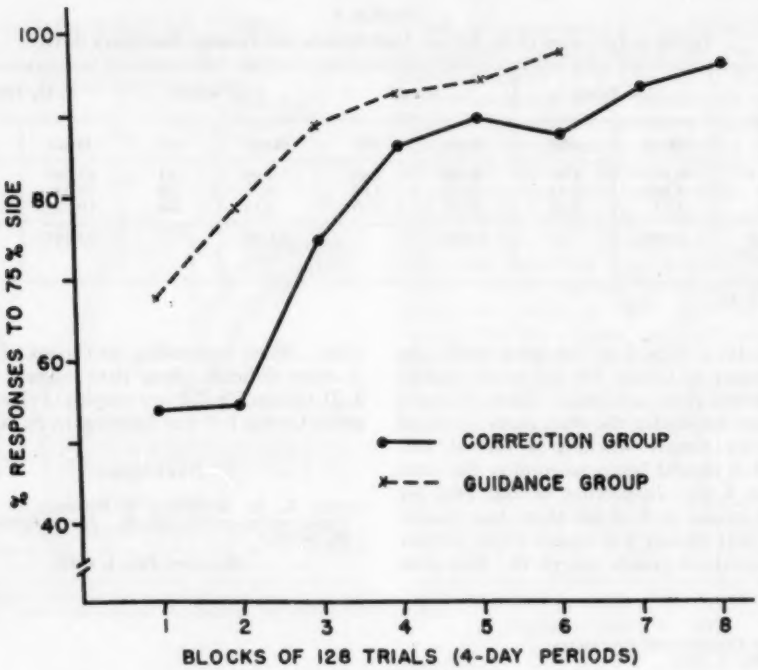

FIG. 1. Mean performance of the two groups.

the more often baited side. The course of mean performance is shown in Fig. 1. Despite the consistent difference in means, there was widespread overlap between the two groups at all points represented. On the last block of trials diagrammed, each of the *Ss* made over 95% choices of the .75 side.[2]

Less ambiguous evidence is thus presented for the conclusion that monkeys will approximate 100% choice of the more often baited side in a .75–.25 noncontingent situation, even when correction is permitted. Furthermore, the same response pattern is seen when a guidance method is used in a contingent situation—although a similar method leads to event-matching behavior in fish (Bitterman et al., 1958).

[2] One additional *S* was tested under the procedures of the Guidance Group, but using a regular RRRL pattern for the placement of reward rather than a random .75–.25 schedule. The behavior of this *S* was not obviously affected by this difference in procedure; his percentages of choice of the right side on successive 128-trial blocks were 67, 70, 73, 84, 90, and 100.

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